Supplemental Environmental Impact Statement for the Designation of Dredged Material Disposal Site(s) in Eastern Long Island Sound, Connecticut and New York

Physical Oceanography of Eastern Long Island Sound Region

Prepared for: **U.S. Environmental Protection Agency**

Sponsored by: **Connecticut Department of Transportation**

Prepared by: **University of Connecticut**

with support from: **Louis Berger**

Public Meetings 5+6 (December 8+9, 2014)

Outline

1. Physical Oceanography in the ZSF – Purpose
2. Model: *Configure and test*
3. Evaluation of Simulations
   - Field Program: *Collect data (currents and stress etc.) at a set of stations that are expected to exhibit a wide range of conditions*
   - Model Performance: *Evaluate predictions of model with new data*
4. Analysis
5. Summary

Physical Oceanography

- Physical oceanography is the science that explains the patterns of ocean circulation and the distribution of properties such as temperature and salinity. Elements of physical oceanography include tides, currents, waves, and sediment transport.

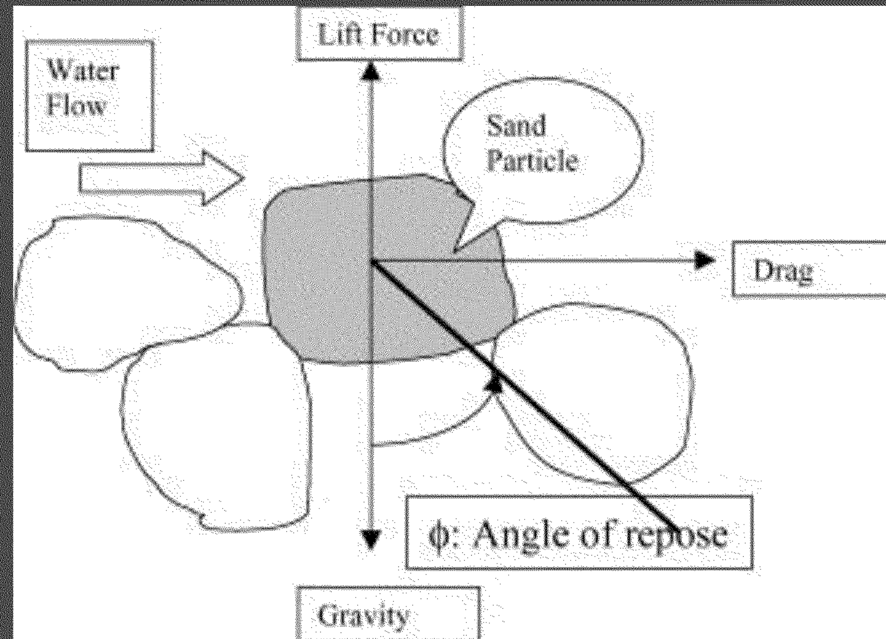
Of particular importance within this study are the factors governing boundary shear stress

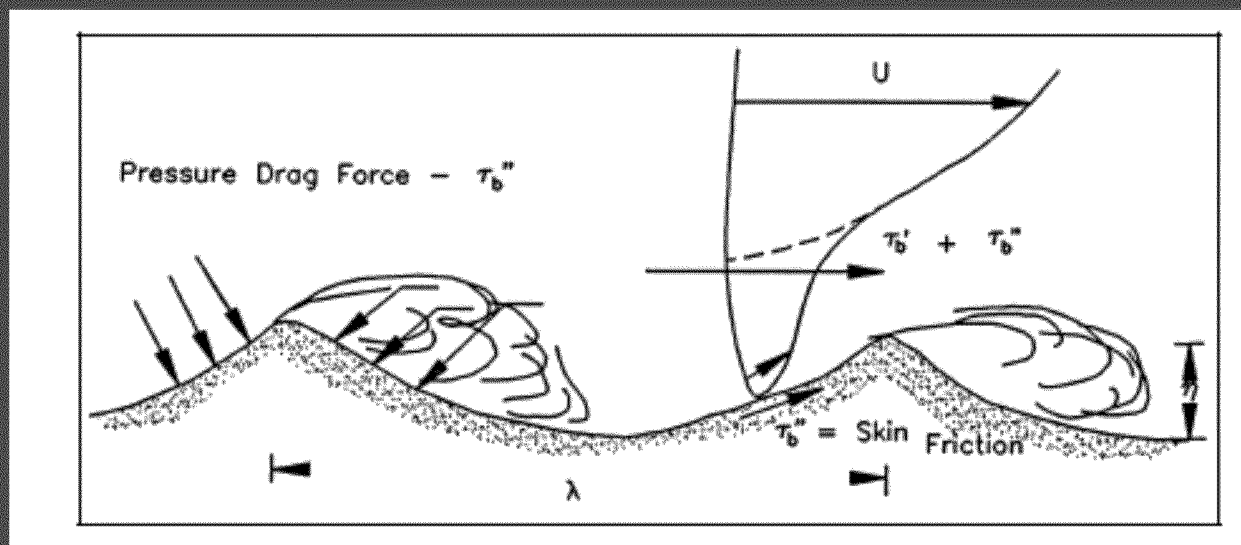
Sediment Transport

For sediment resuspension the lift force due to the flow around it must exceed the gravity force.

The lift and drag forces slow the water and this effective force per unit area is called the **shear stress**.

Bedforms have a similar effect on the flow… they slow it down.





Critical Erosion Stress

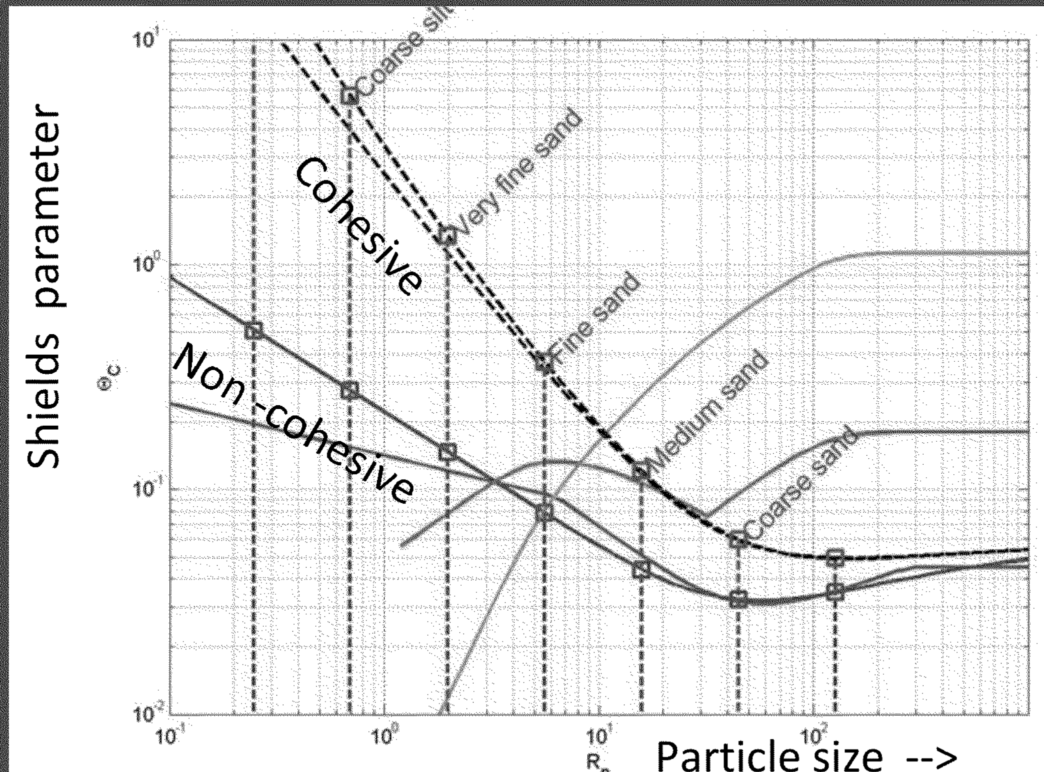


Figure 34. A graphical representation of the relationship between sediment particle size for cohesive and non-cohesive particles.

The red and blue solid lines are analytical representations of the critical Shields parameter, $\Theta_{c0} = \tau_{c0}/\rho_w sgd$, for non-cohesive sediments as a function of the particle Reynolds number. The black dashed lines show the influence of cohesion and adhesion on the critical value for the onset of particle motion.

The green and magenta lines show the critical values for the onset of sediment suspension as predicted by Bagnold (1966) and van Rijn (1984), respectively. The lower boundaries of the particle Reynolds numbers for traditional sediment classes (see Table 7) are shown by the blue dashed lines.

Particle Size and Critical Stress for Cohesive and Non-cohesive Sediments

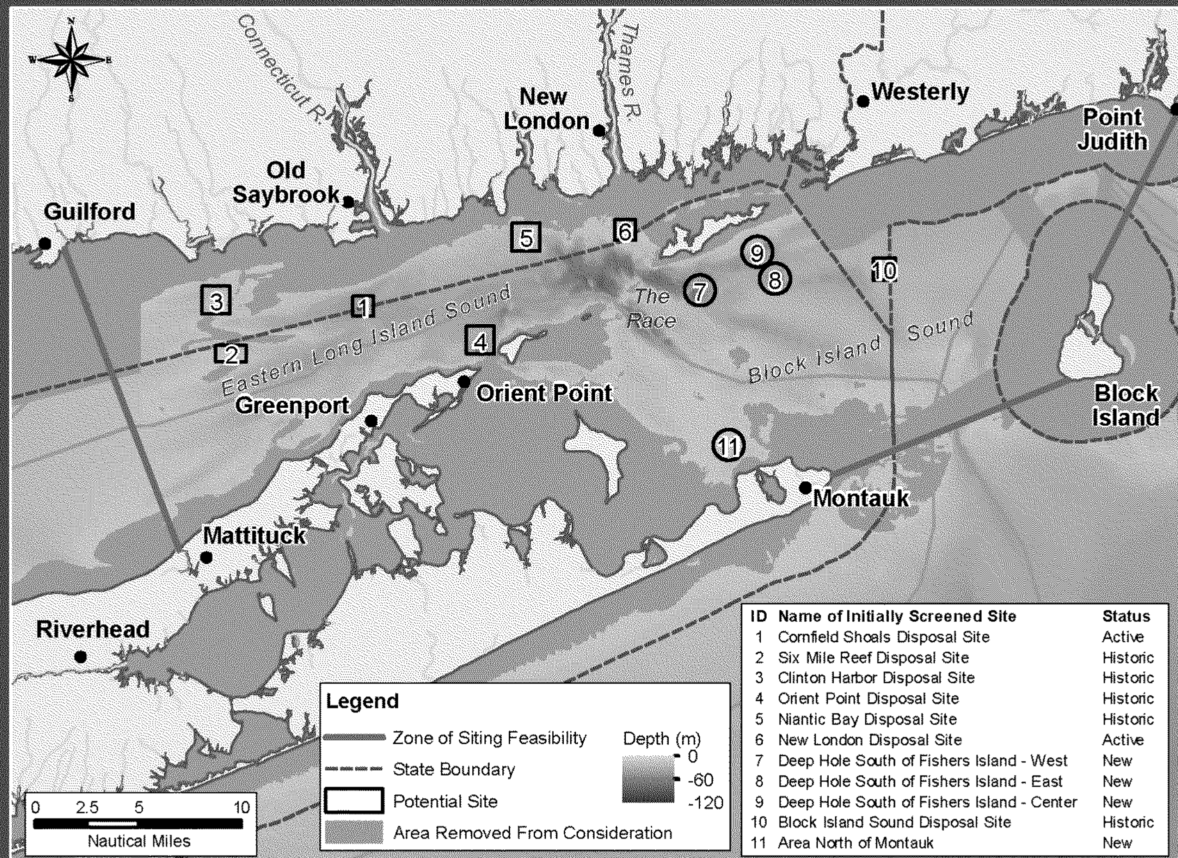
Size				Non-Cohesive Sediments			Cohesive Sediments		
	Particle Size		Reynolds Number	Critical Shields Parameter	Critical Stress	Critical Velocity	Critical Shields Parameter	Stress at the Initiation of Motion	Critical Velocity
Classification	Phi	d (mm)	R_p	Θ_{c0}	τ_{c0} (Pa)	$u_{1,0}$ (m/s)	Θ_c	τ_c (Pa)	u_1 (m/s)
Column No.	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Coarse sand	1-0	0.50	44.96	0.03	0.26	0.32	0.06	0.48	0.44
Medium sand	2-1	0.25	15.90	0.04	0.18	0.27	0.12	0.49	0.44
Fine sand	3-2	0.13	5.62	0.08	0.16	0.25	0.37	0.74	0.54
Very fine sand	4-3	0.06	1.99	0.15	0.15	0.24	1.33	1.35	0.73
Coarse silt	5-4	0.03	0.69	0.27	0.14	0.23	5.62	2.81	1.06
Medium silt	6-5	0.02	0.25	0.51	0.13	0.23	26.33	6.64	1.63
Fine silt	7-6	0.01	0.09	0.95	0.12	0.22	143.41	18.09	2.69

Notes: Columns 5 to 7 provide example magnitudes of the critical shields parameter, Θ_{c0}, for non-cohesive sediments and the stress τ_{c0} at the initiation of motion for the lower bounds for specific particle size classes listed on the left. An estimate of the magnitude of the required current at 1m above the sea floor required to create the critical stress for non-cohesive sediments is provided as $u_{1,0} = \sqrt{\tau_{c0}/\rho C_d}$ where $C_d = 2.5 \times 10^{-3}$ is assumed. Analogous estimates for cohesive sediments are provided Columns 8 to 10 based on the theory presented by Righetti and Lucarelli (2007). Values shaded in blue are extrapolations beyond the range of particle sizes used in parameterization.

Objective of PO Study

Support evaluation and selection of potential dredged material disposal sites within the Zone of Siting Feasibility (ZSF)

- Describe distribution of <u>maximum bottom stress magnitudes</u> expected in the ZSF including 'Superstorm Sandy' conditions (100-year storm)
- Characterize <u>circulation</u> in the ZSF to support assessment of potential off-site effects
- Acquire physical oceanography data to support future <u>modeling of sediment transport</u> at potential dredged material disposal sites

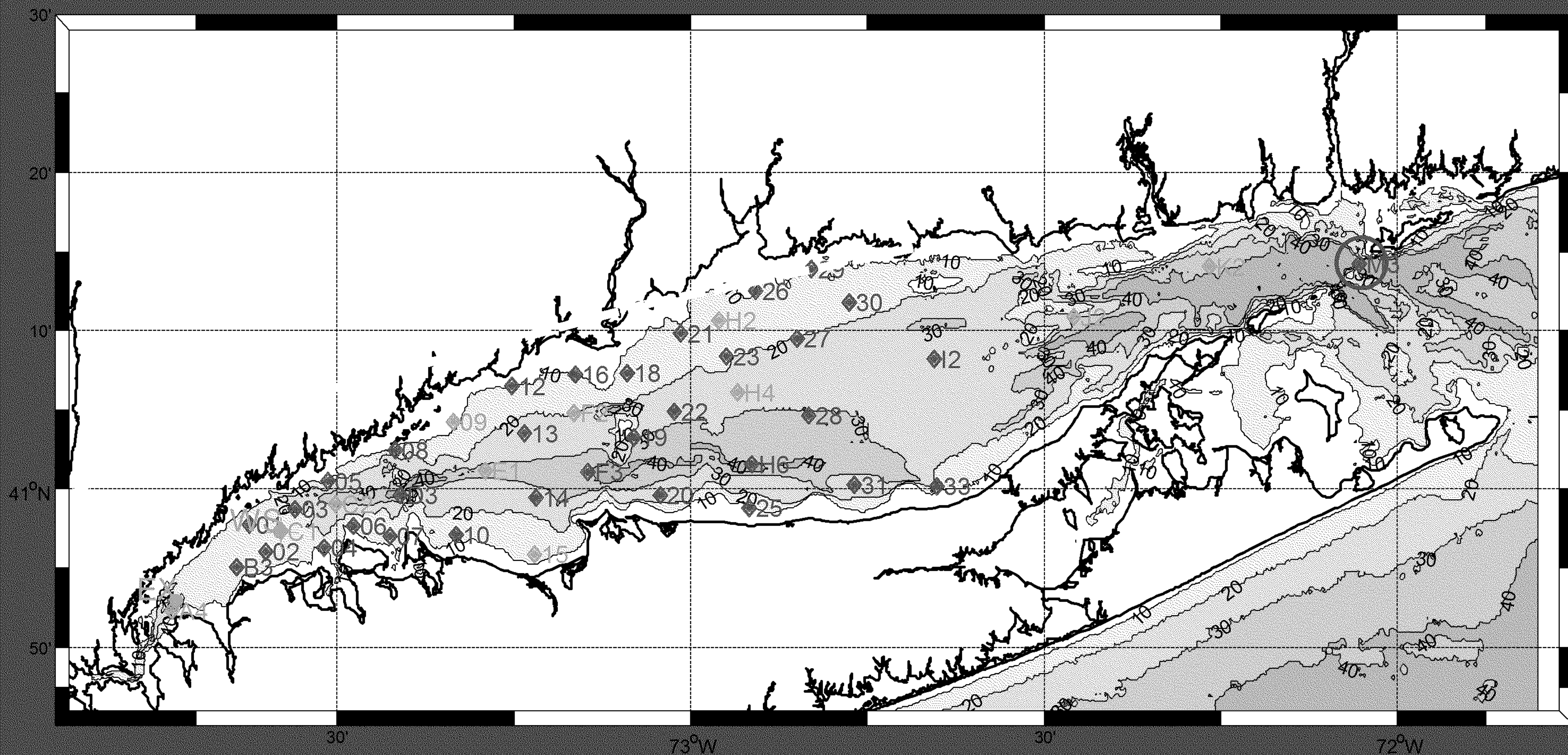


ID	Name of Initially Screened Site	Status
1	Cornfield Shoals Disposal Site	Active
2	Six Mile Reef Disposal Site	Historic
3	Clinton Harbor Disposal Site	Historic
4	Orient Point Disposal Site	Historic
5	Niantic Bay Disposal Site	Historic
6	New London Disposal Site	Active
7	Deep Hole South of Fishers Island - West	New
8	Deep Hole South of Fishers Island - East	New
9	Deep Hole South of Fishers Island - Center	New
10	Block Island Sound Disposal Site	Historic
11	Area North of Montauk	New

Zone of Siting Feasibility (ZSF). Initial screening identified (1) areas not suitable for locating dredged material disposalsites due to various constraints (gray zone), and (2) 11 sites for further investigation as potential disposal sites; these sites include two active and five historic disposal sites, and six 'new' sites not previously used for dredged material disposal. The backgroundrepresents water depth.

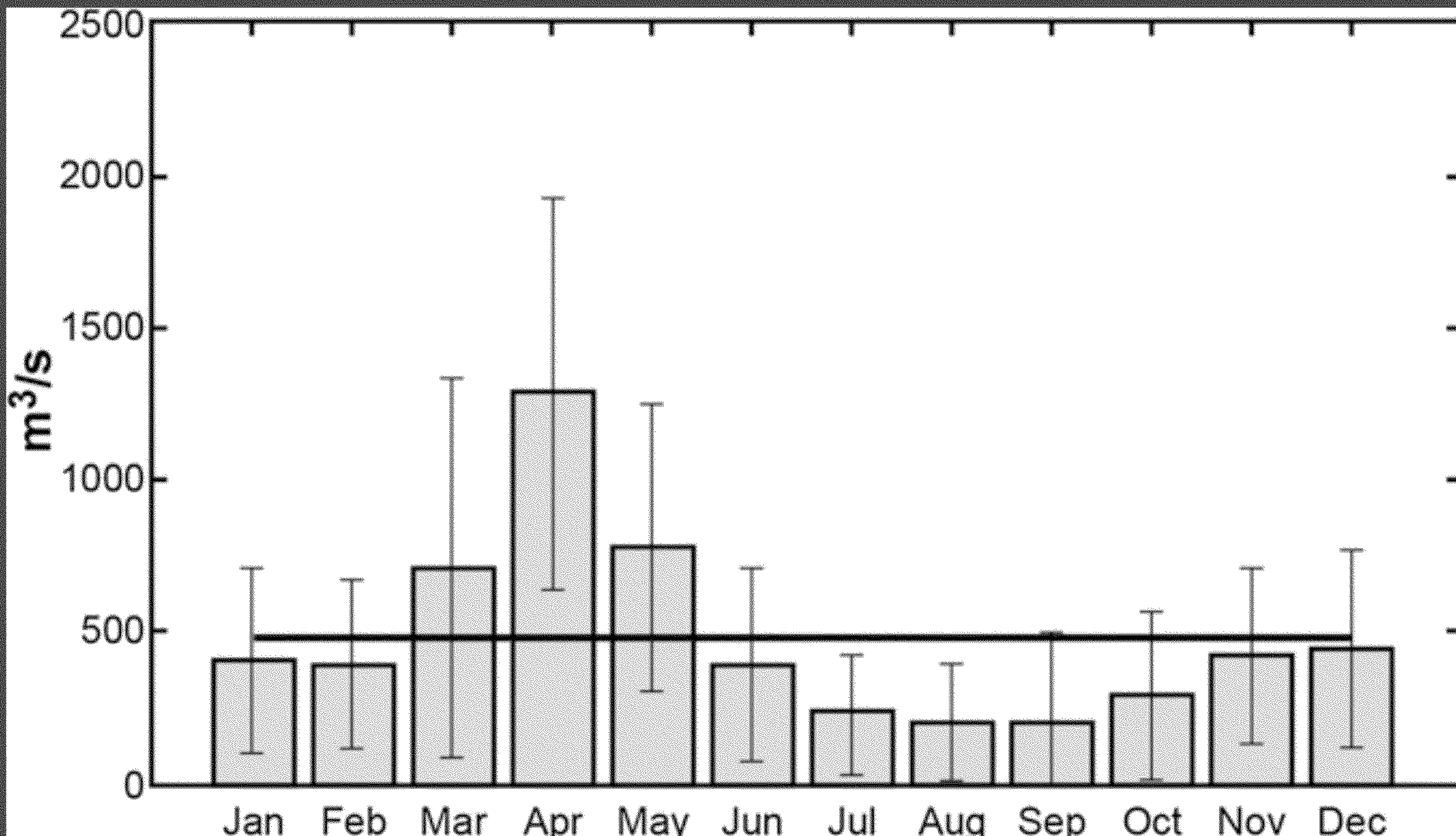
Regional Temperature and Salinity

CTDEEP – EPA Long Island Sound Study Ship Survey Stations

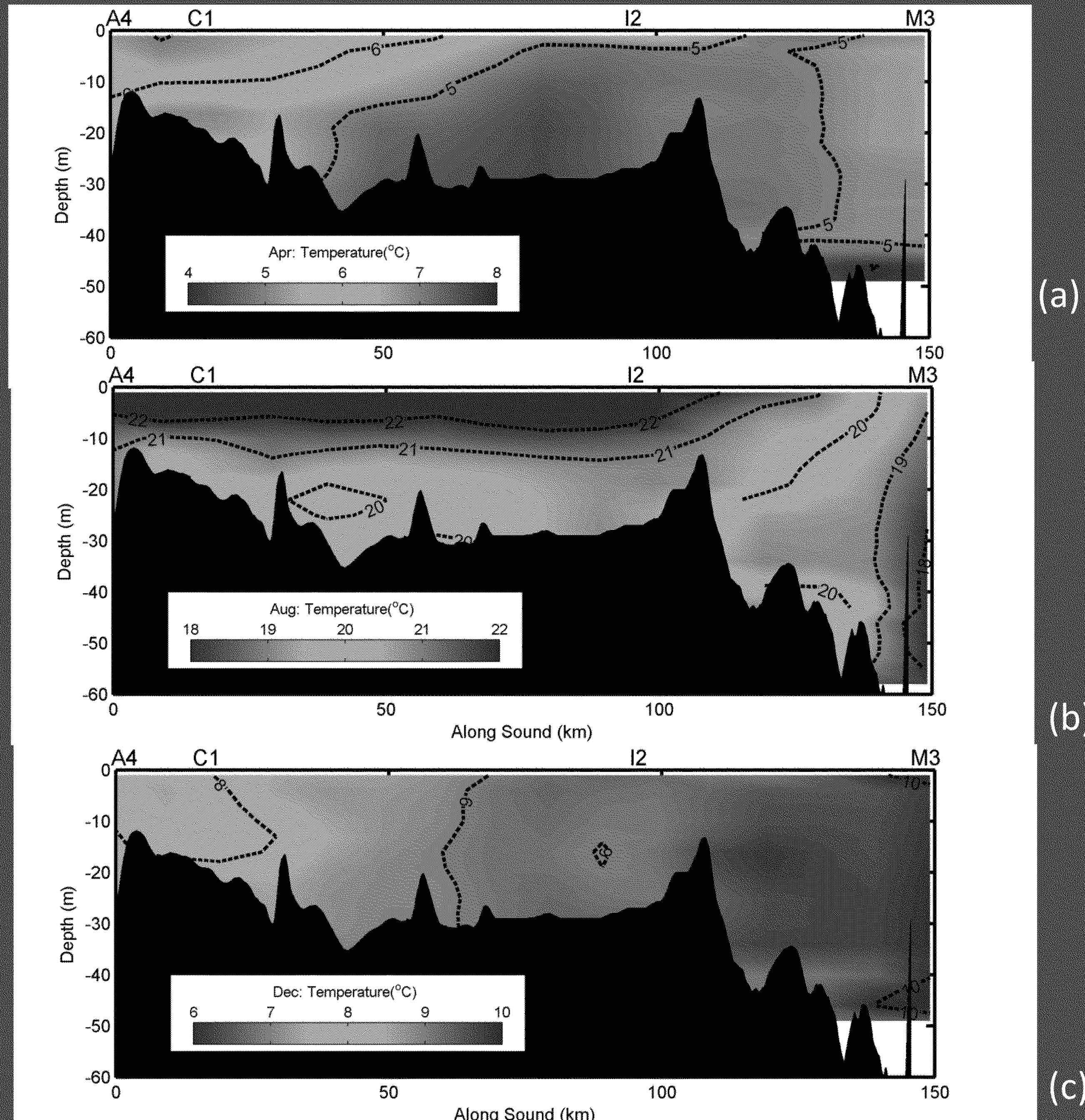


River Inflow

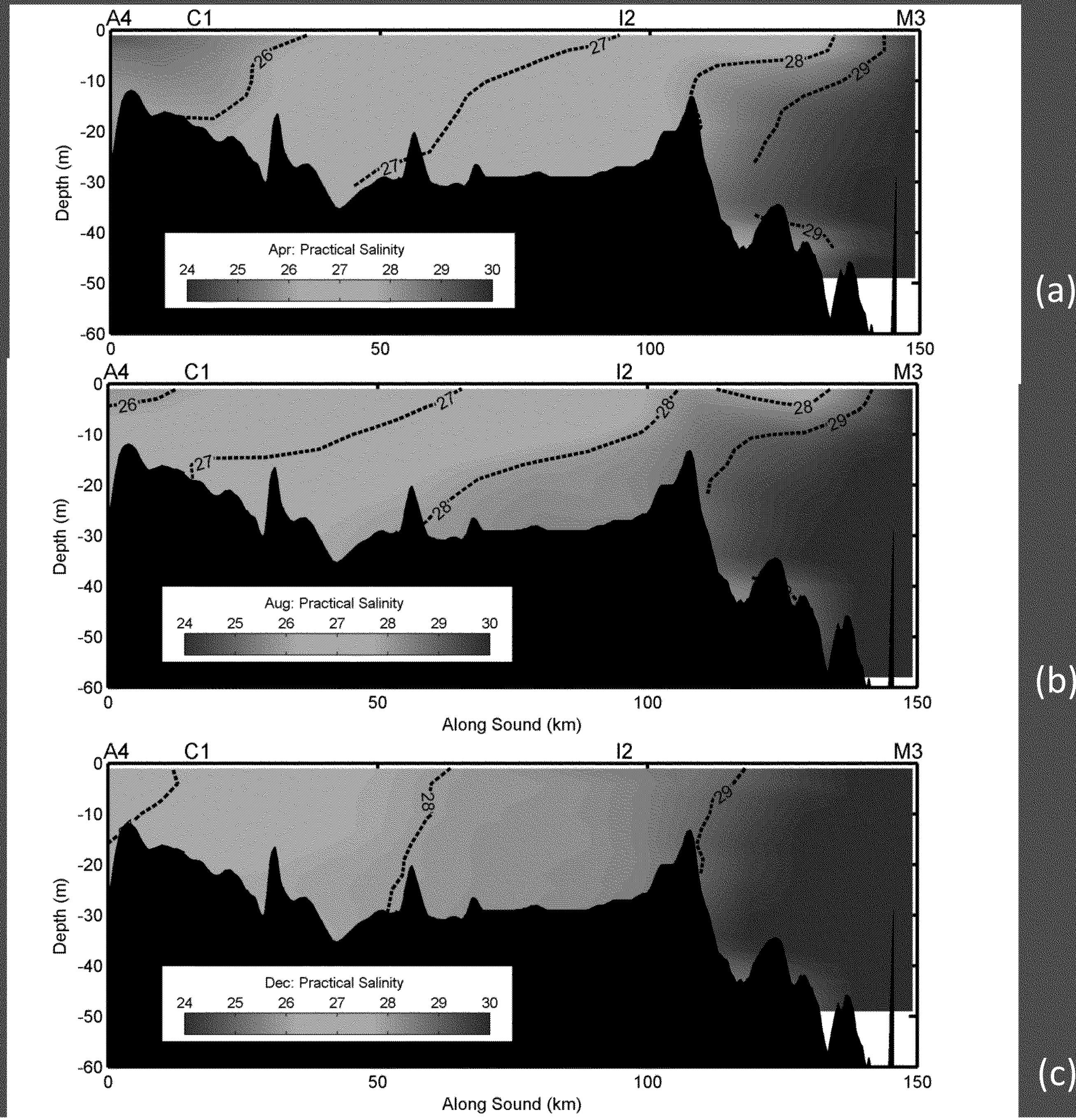
Monthly Discharge of Connecticut Rivers (~80% of total inflow to Long Island Sound)



Water Tempe-rature



Salinity



A4
C1
I2
M3
Depth (m)
Apr: Practical Salinity
24 25 26 27 28 29 30
Aug: Practical Salinity
24 25 26 27 28 29 30
Dec: Practical Salinity
24 25 26 27 28 29 30
Along Sound (km)
(a)
(b)
(c)

Tidal Current Oscillations

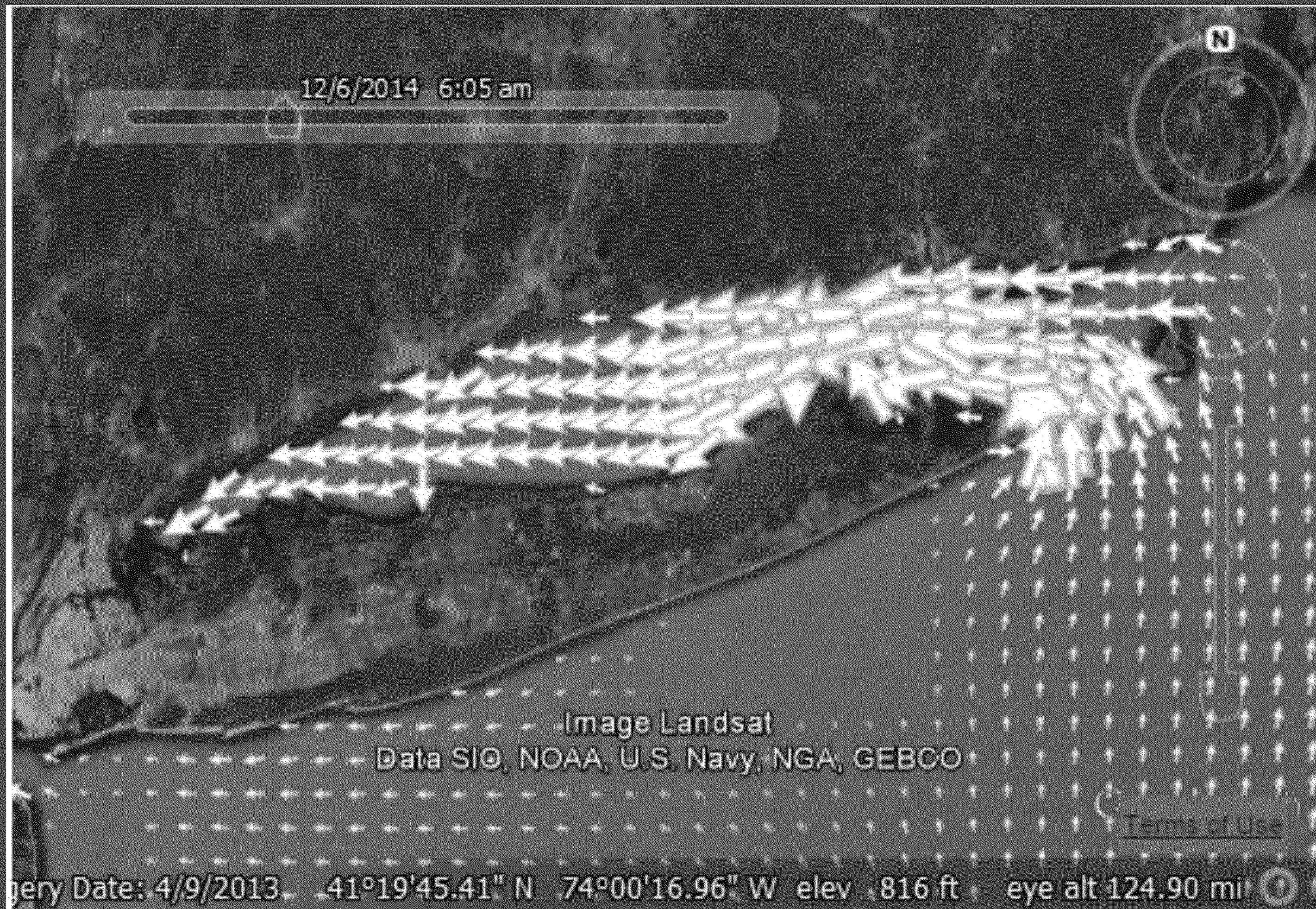
- 00:00 AM

Tidal Current Oscillations

- 03:00 AM

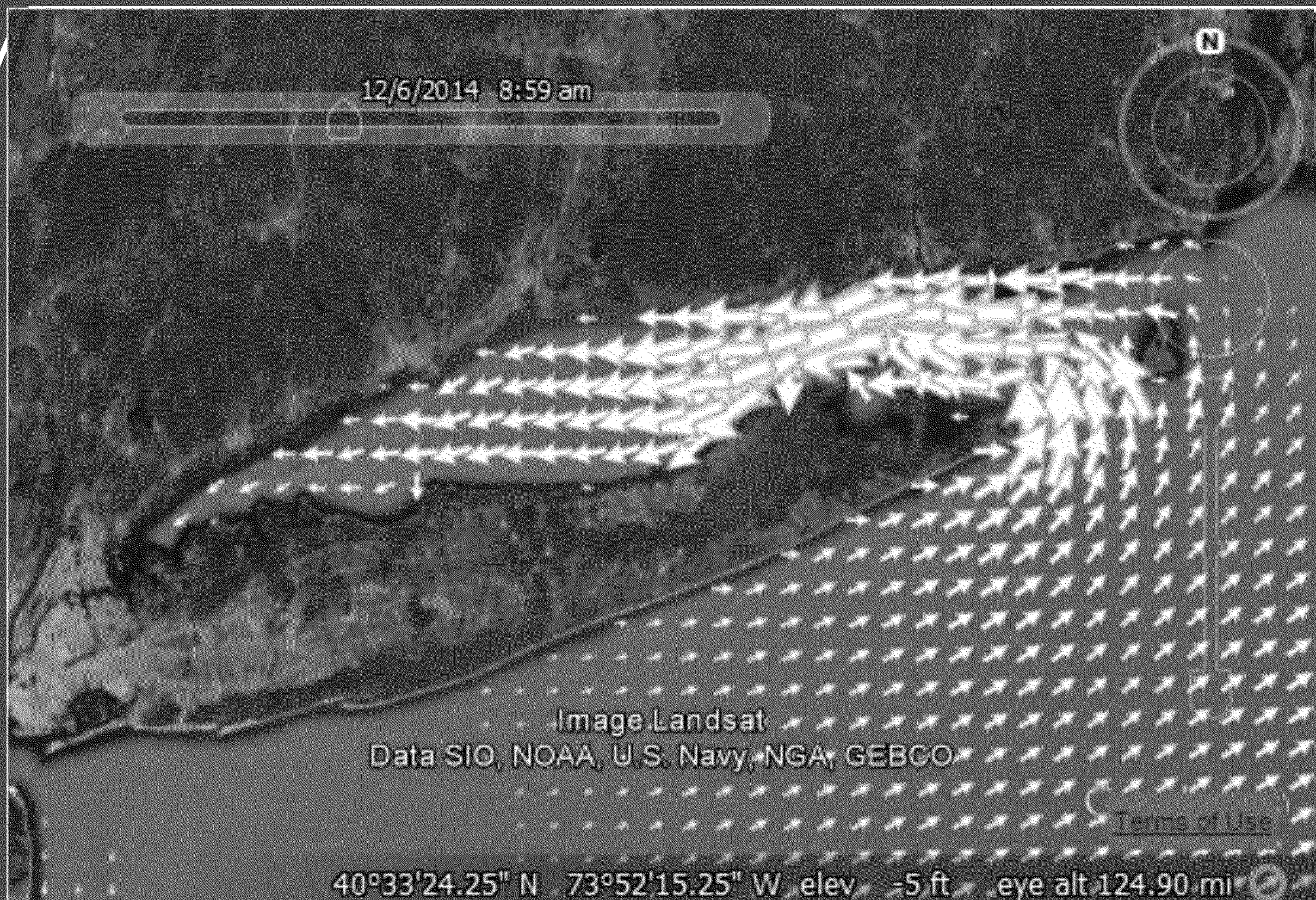
Tidal Current Oscillations

- 06:00 AM



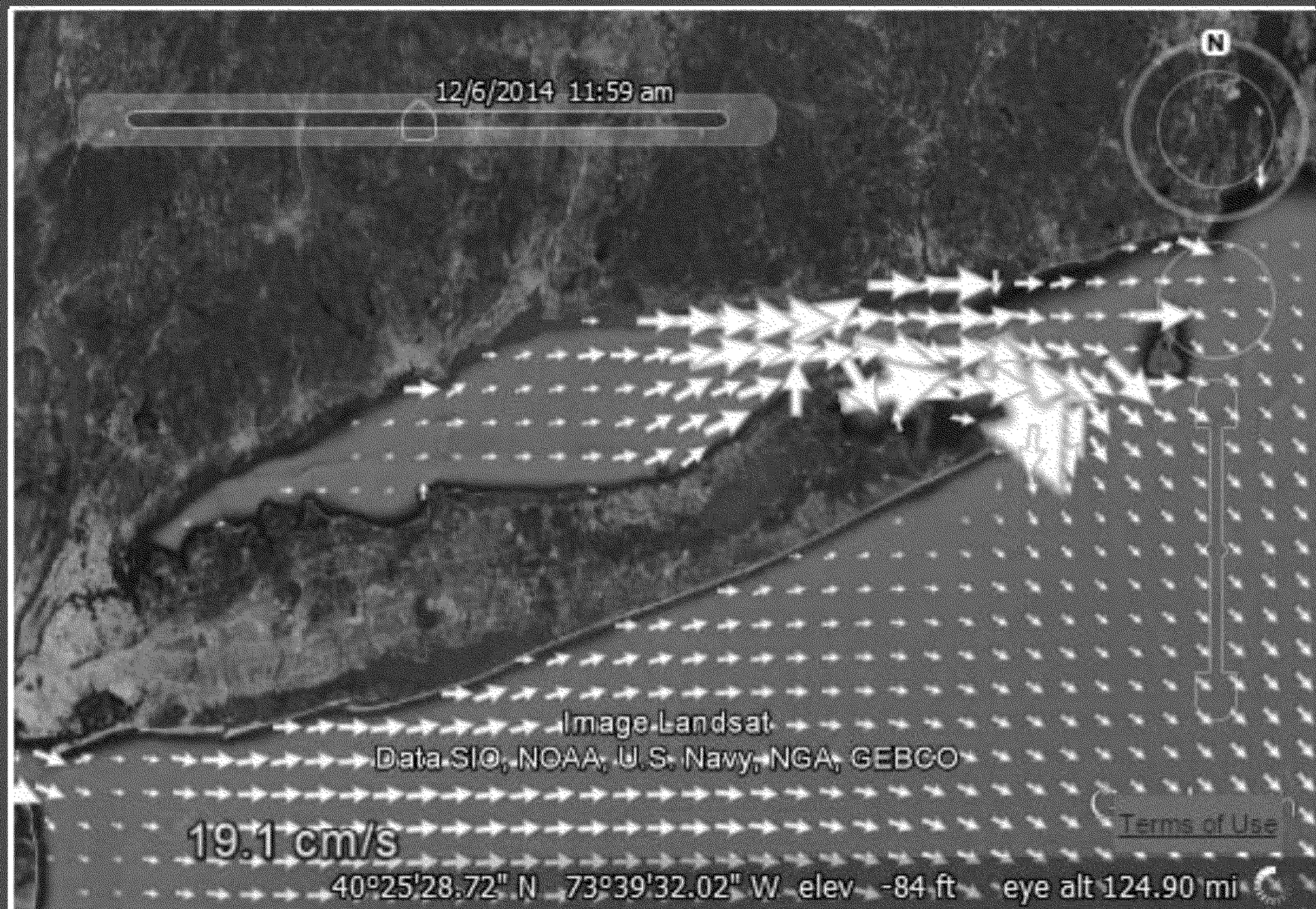
Tidal Current Oscillations

- 09:00 AM

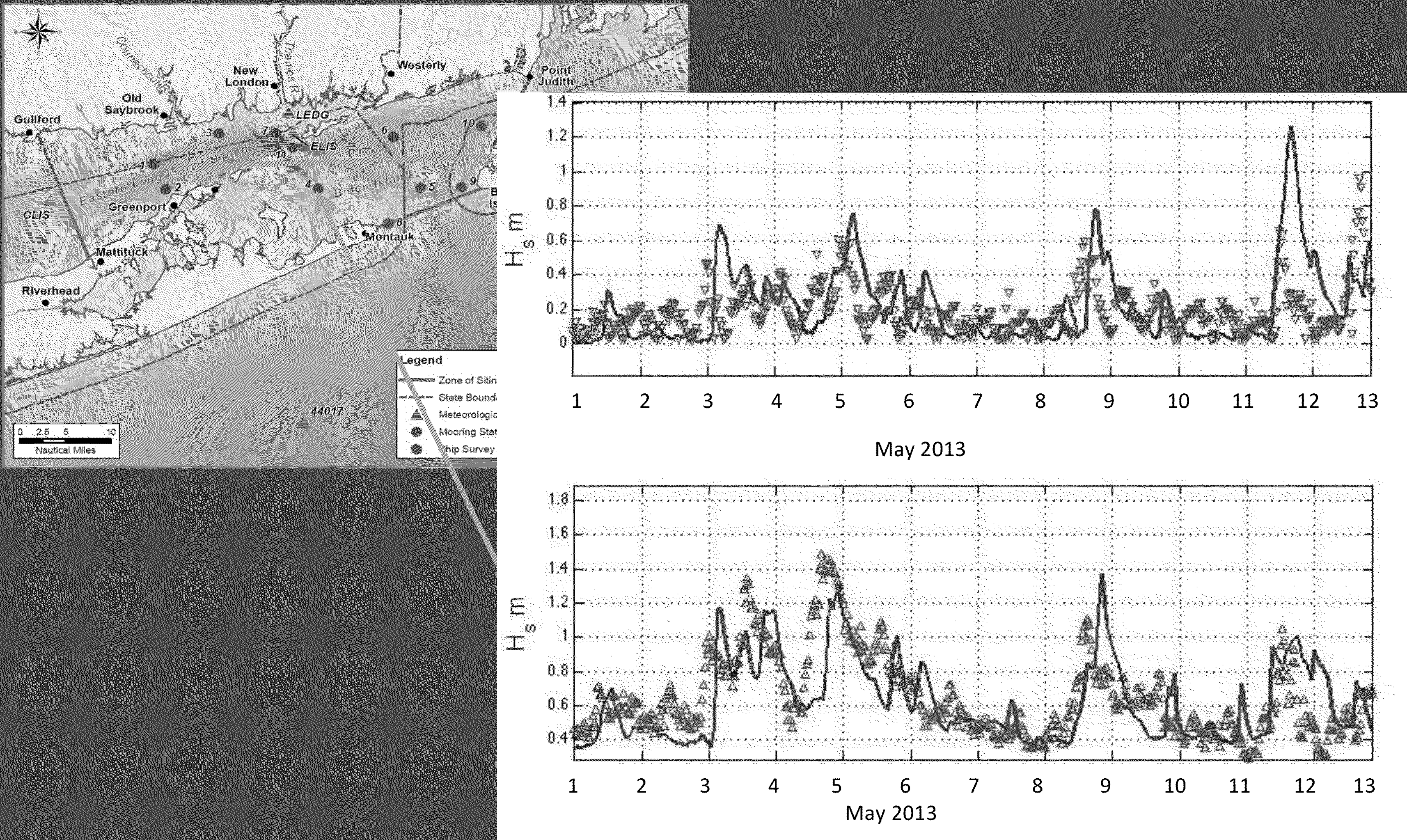


Tidal Current Oscillations

- 12:00 AM



Significant Wave Height Observations *(red)*



Comparison of model and observed significant wave height at Stations DOT1 (upper panel) and DOT4 (lower panel) during May 2013.

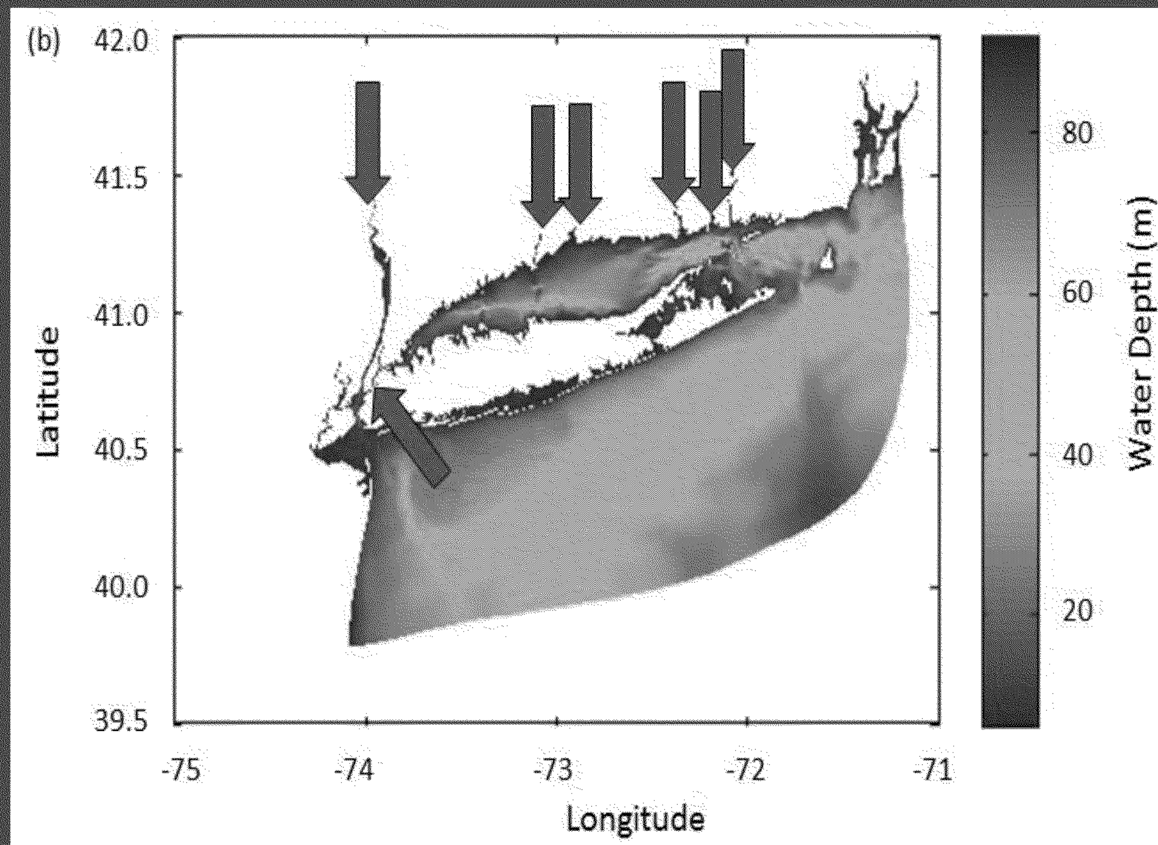
2. Model – Questions for Study

- What is the distribution and spatial variation in the bottom stress?
- Where are the regions in which the maximum stresses are smallest?
- Where does material in the water at potential sites go?

2. Model

FVCOM - Finite Volume Community Ocean Model

- Developed by Prof. Chen, Univ.of Massachusetts, adapted for Long Island Sound
- Nested within NECOFS (Northeast Coastal Ocean Forecast System)
- Forced by:
  - Tides
  - Observed River flow and wind
  - Climatology for surface heat exchange
  - Climatology for initial conditions



Bathymetry of the LIS model subdomain with the locations of freshwater sources (green arrows; from left to right: Hudson River, New York City wastewater treatment plants , Housatonic River, Quinnipiac River, Connecticut River, Niantic River, and Thames River).

2. Model *(cont.)*

An Unstructured Grid, Finite-Volume, Three-Dimensional, Primitive Equations Ocean Model: Application to Coastal Ocean and Estuaries

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ROBERT C. BEARDSLEY

Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

The "Model" is based on Newton's laws.

It predicts the water velocity, level, temperature and salinity.

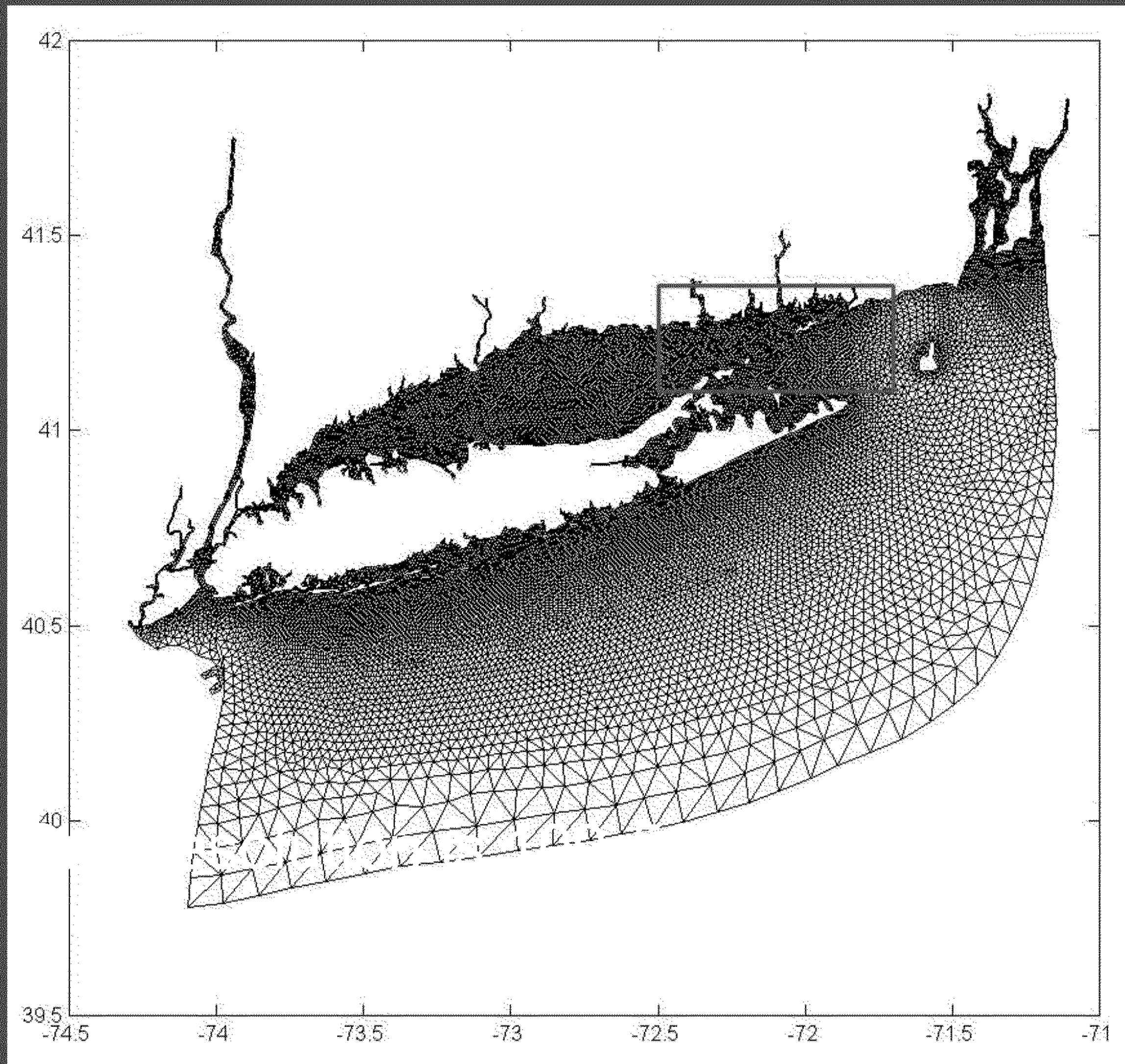
The bottom stress magnitude is computed from the formula

$$\tau = \rho C_D (u^2 + v^2)$$

Where the coefficient $C_{D,}$ is called the DRAG COEFFICIENT.

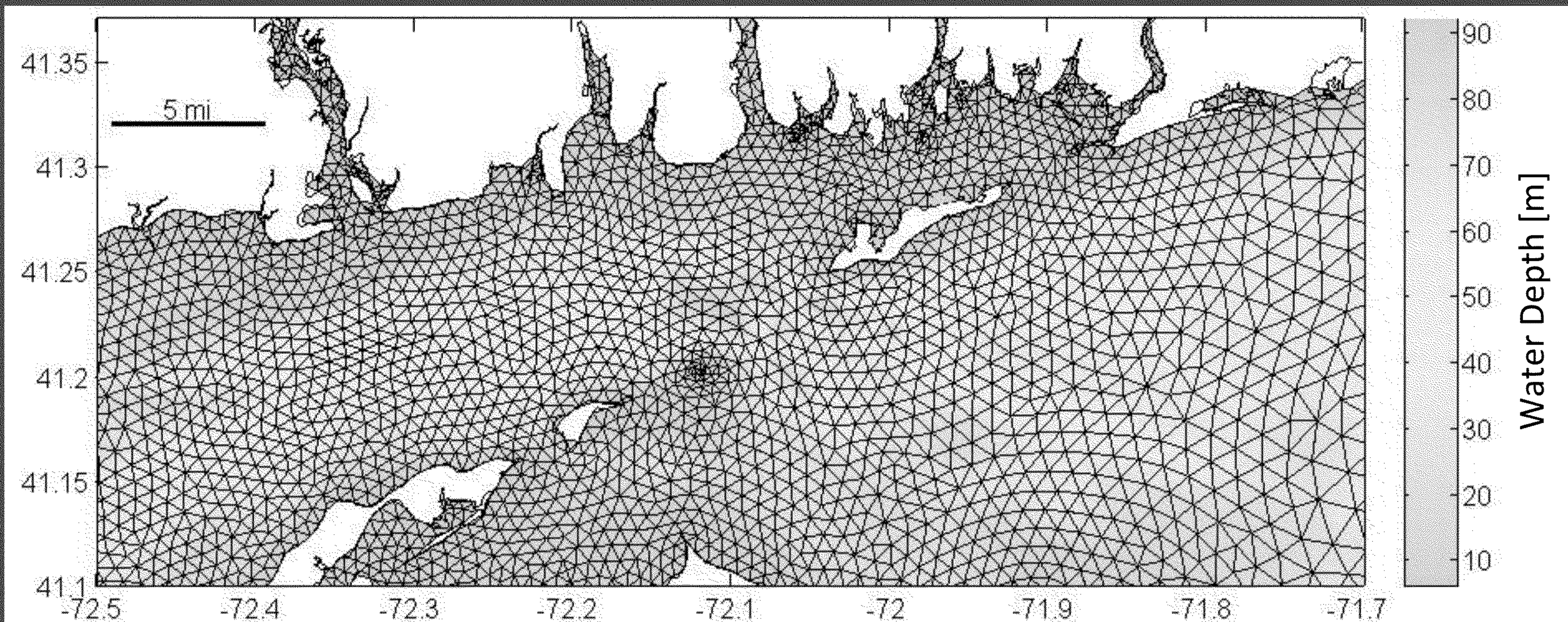
2. Model *(cont.)*

FVCOM runs on an unstructured triangular grid (mesh)



2. Model *(cont.)*

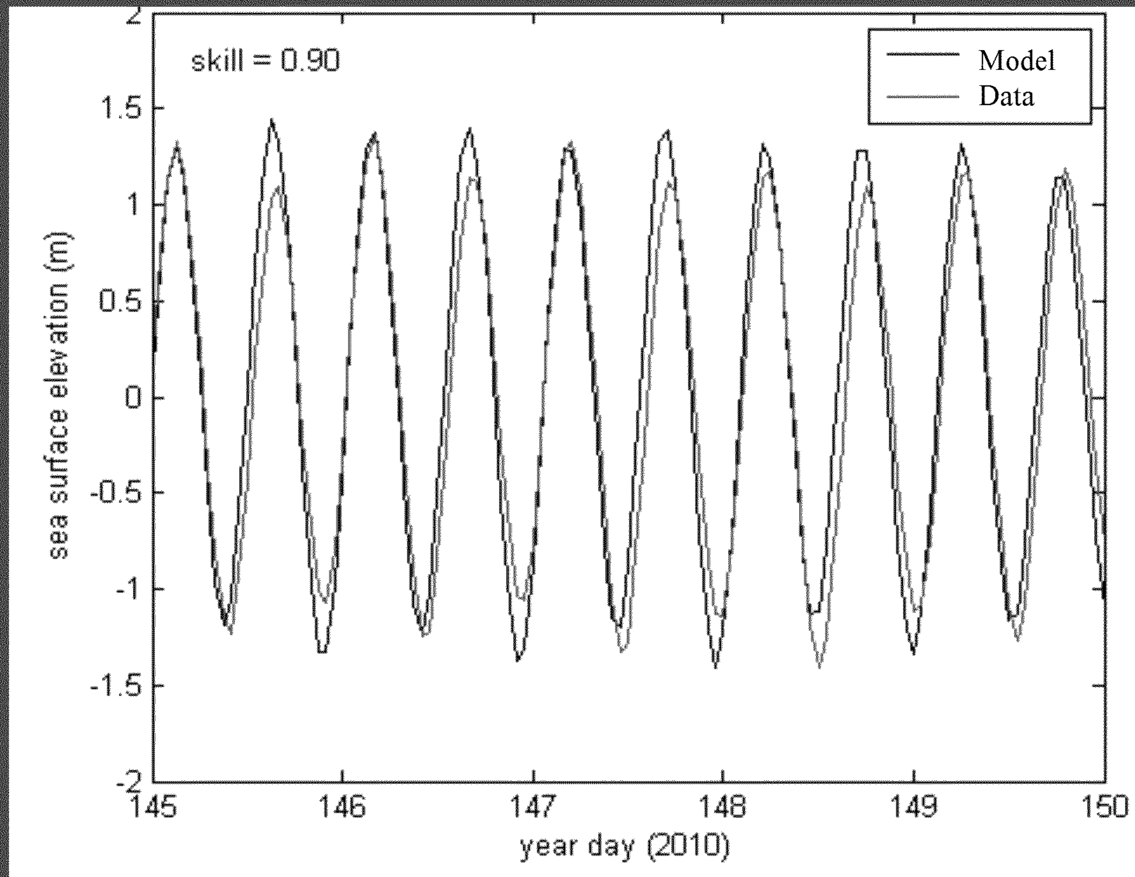
FVCOM runs on an unstructured triangular grid (mesh)



Grid resolution is 100-500 m (~ ¼ mile)

2. Model Calibration

- Optimize the simulation of sea level, temperature, and salinity compared to observations
- Determine the Skill (variance in data explained/variance in data) to be 90%

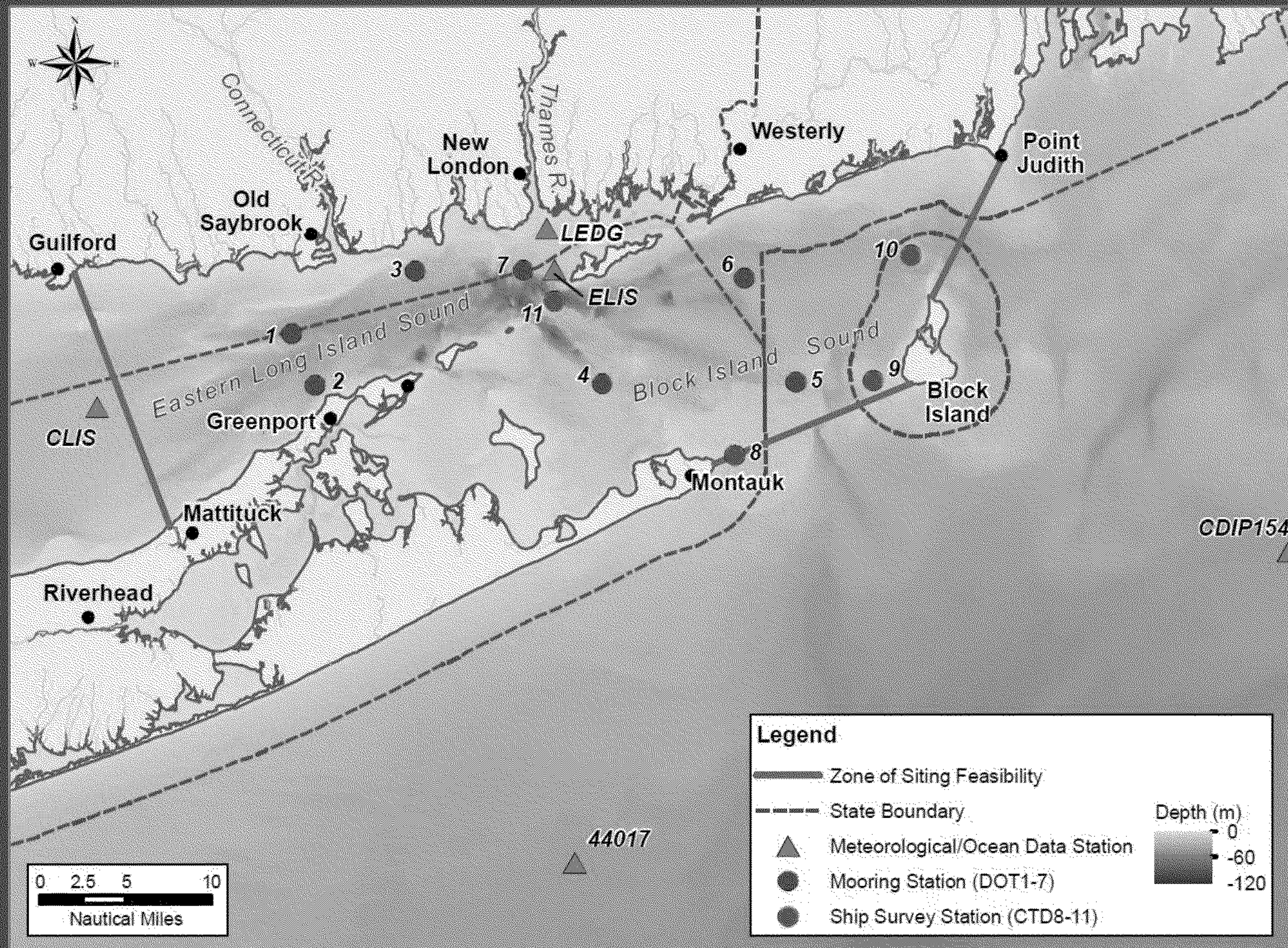


Comparison of tidal heights at the NOAA Bridgeport tidal height gauge (BDR, blue) compared to those predicted by the FVCOM model (black) after iteratively calibrating the model using the 2010 NOAA data . Note that year day 1 is January 1, 2010.

3. Evaluation – Field Program

- Deploy instruments on 7 bottom tripods for 3 two-month observation campaigns to observe spring, fall winter conditions at locations having differing stresses etc

- Conduct 6 cruises with water column measurements at the 7 tripod stations and 4 additional stations



Survey stations in the ZSF, as well as meteorological/oceanstations. The background represents water depth.

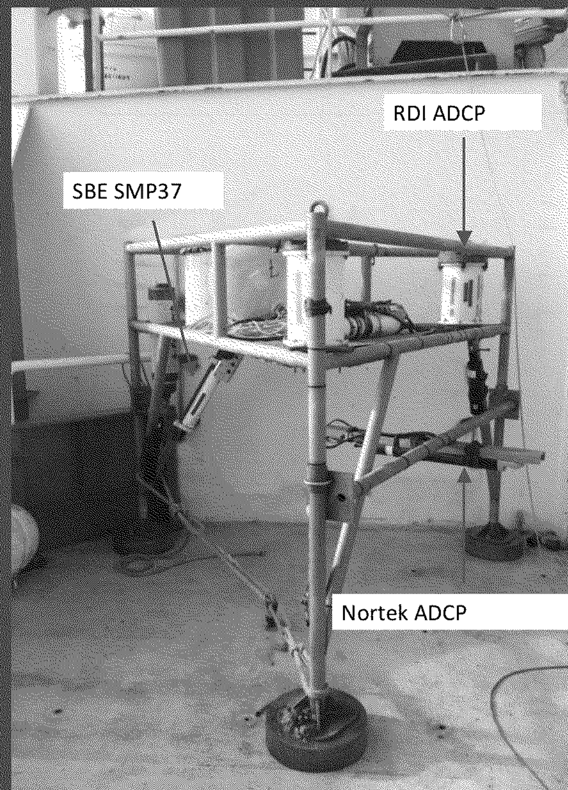
Survey periods

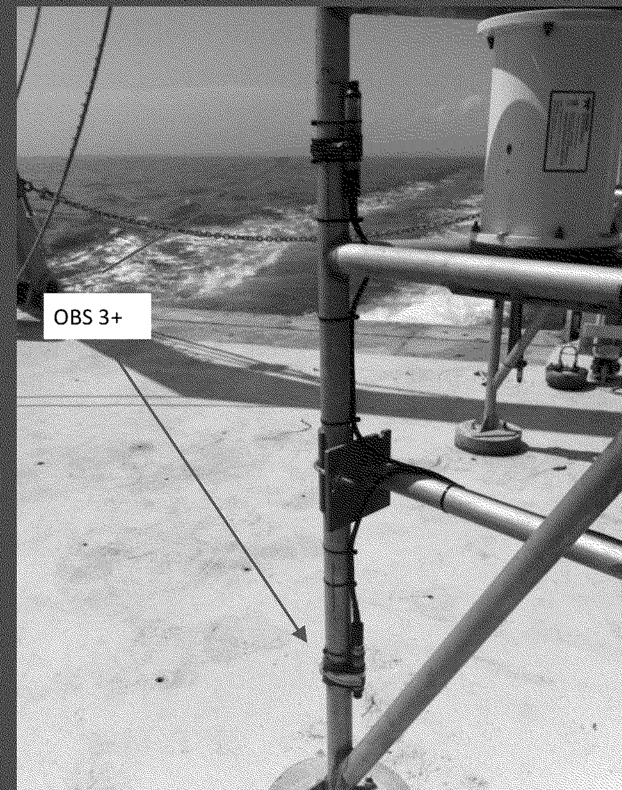
Campaign	Period	Interval	Conditions
1	Spring	March 12 - May 17, 2013 *(66 days)*	High river flow High wind
2	Summer	June 11 – Aug. 8, 2013 *(58 days)*	Low river flow, Low wind
3	Winter	Nov. 20, 2013 – Jan. 16, 2014 *(57 days)*	Low river flow, High wind

Moored Instruments

Sensors:

- Water column currents and waves
  (upward looking RDI ADCP)
- Currents near Seafloor - Stress
  (downward looking Nortek ADCP)
- Suspended sediment concentration
  (2 optical backscatter OBS3+)
- Salinity and temperature
  (CTD SBE SMP37)

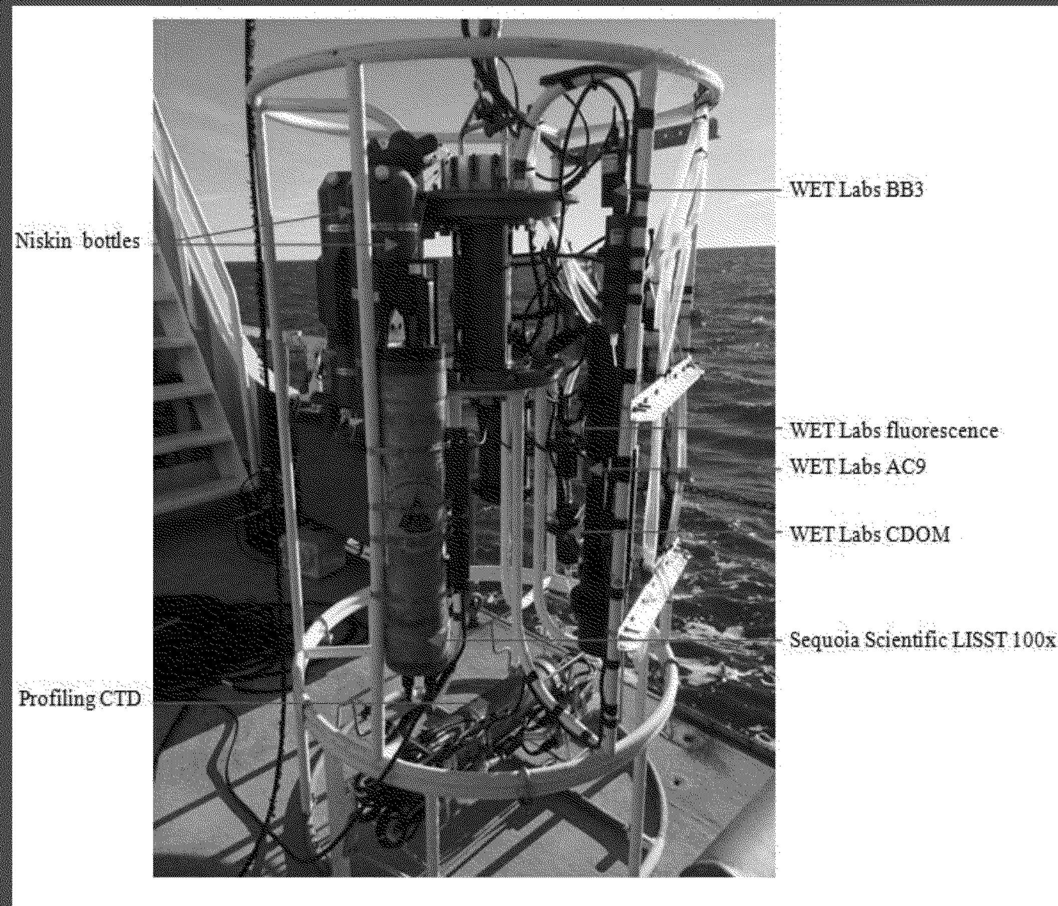




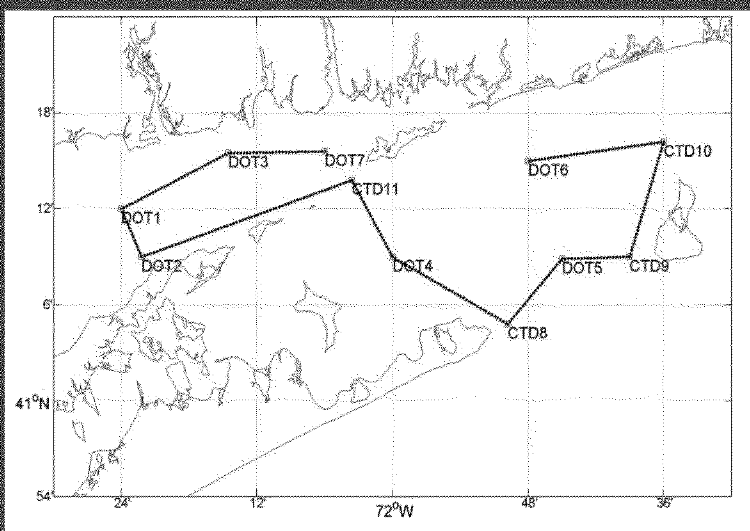
Left: Location of instruments in moored tripod frame
Right: Close-up of the OBS3+ mounts

Ship Surveys

- Temperature and salinity
  (Profiling CTD)
- Suspended sediment
  (WET Labs sensors)
- Water sampling
- Sediment Sampling

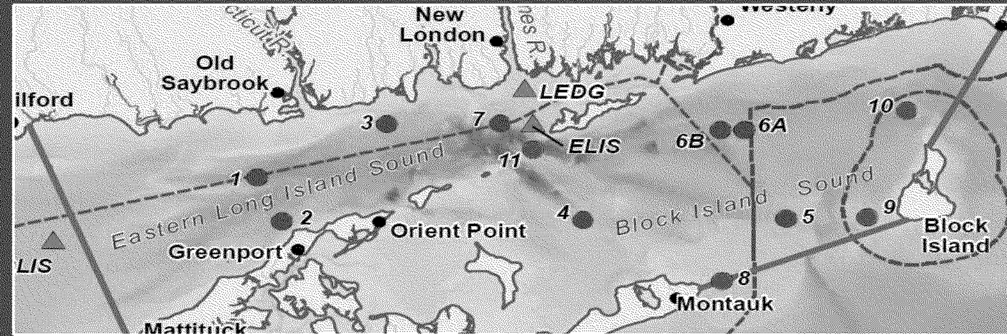


Rosette sampler, equipped with a profiling CTD, Water samplers, and various optical sensors and particle analyzers.



Example of a cruise track for ship surveys. The track varied for each cruise due to weather conditions and sea state.

Data Recovery



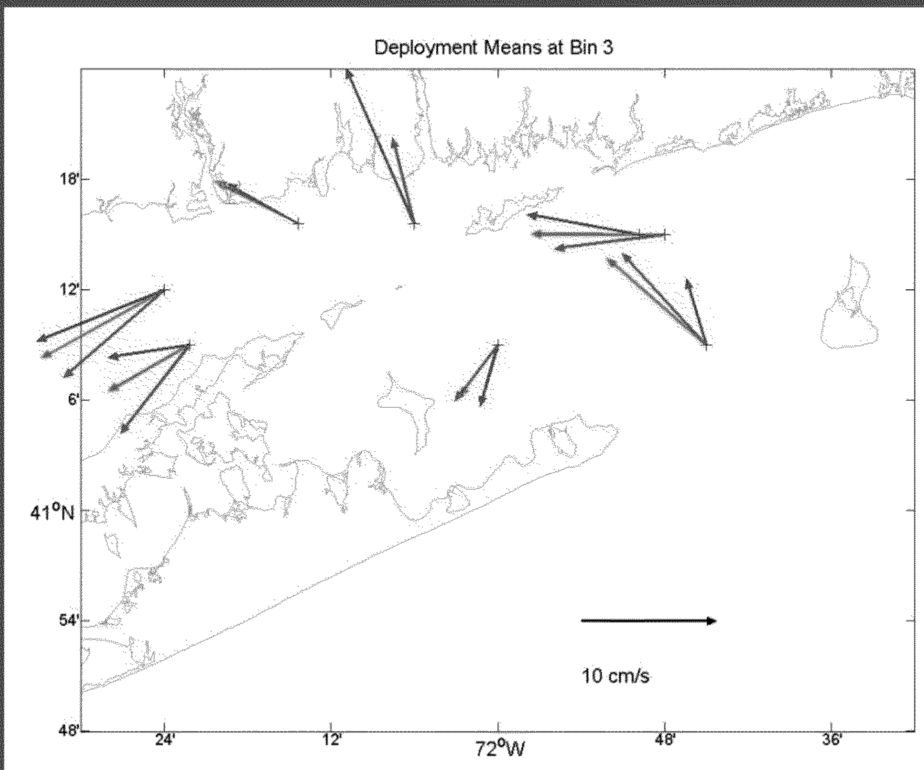
For Moored Stations

Para-meters	Temperature and Salinity near the Seafloor				Currents and Suspended Sediment near the Seafloor				Waves and Currents in the Water Column			
Sensor	*CTD (SBE SMP37)*				*Nortek ADCP & OBS3+ sensor*				*RDI ADCP*			
Mooring Stn	Campaign			Total	Campaign			Total	Campaign			Total
	1	2	3		1	2	3		1	2	3	
	days				days				days			
DOT1	66	58	57	181	25	29	54	108	66	58	57	181
DOT2	66	58	57	181	25	27	54	106	66	58	57	181
DOT3	66	58	57	181	24	32	53	110	0	58	57	115
DOT4	66	58	57	181	27	34	56	117	66	58	57	181
DOT5	66	58	57	181	27	30	57	114	66	58	57	181
DOT6 A/B	66	58	43	167	25	16	44	86	28	16	43	87
DOT7	49	58	57	164	28	34	27	89	0	58	57	115
Max Days	*66*	*58*	*57*	*181*	*66*	*58*	*57*	*181*	*66*	*58*	*57*	*181*

Full or near-full data (>90%)
About half or more data (45 - 90%)
About one quarter or more data (22.5 - 45%)
No data

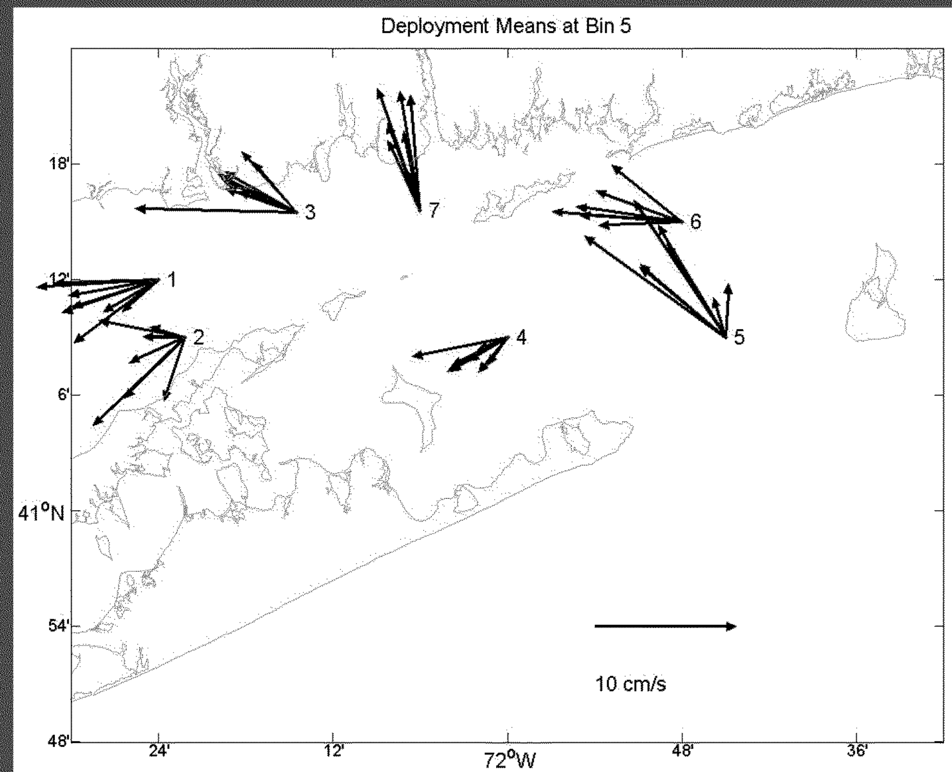
Example of Observations – mean flow near the bottom

RDI ADCP means at ~3m from seafloor



Mean currents at Bin 3 of the RDI ADCP measurements during Campaigns 1 (green), 2 (red), and 3 (blue).

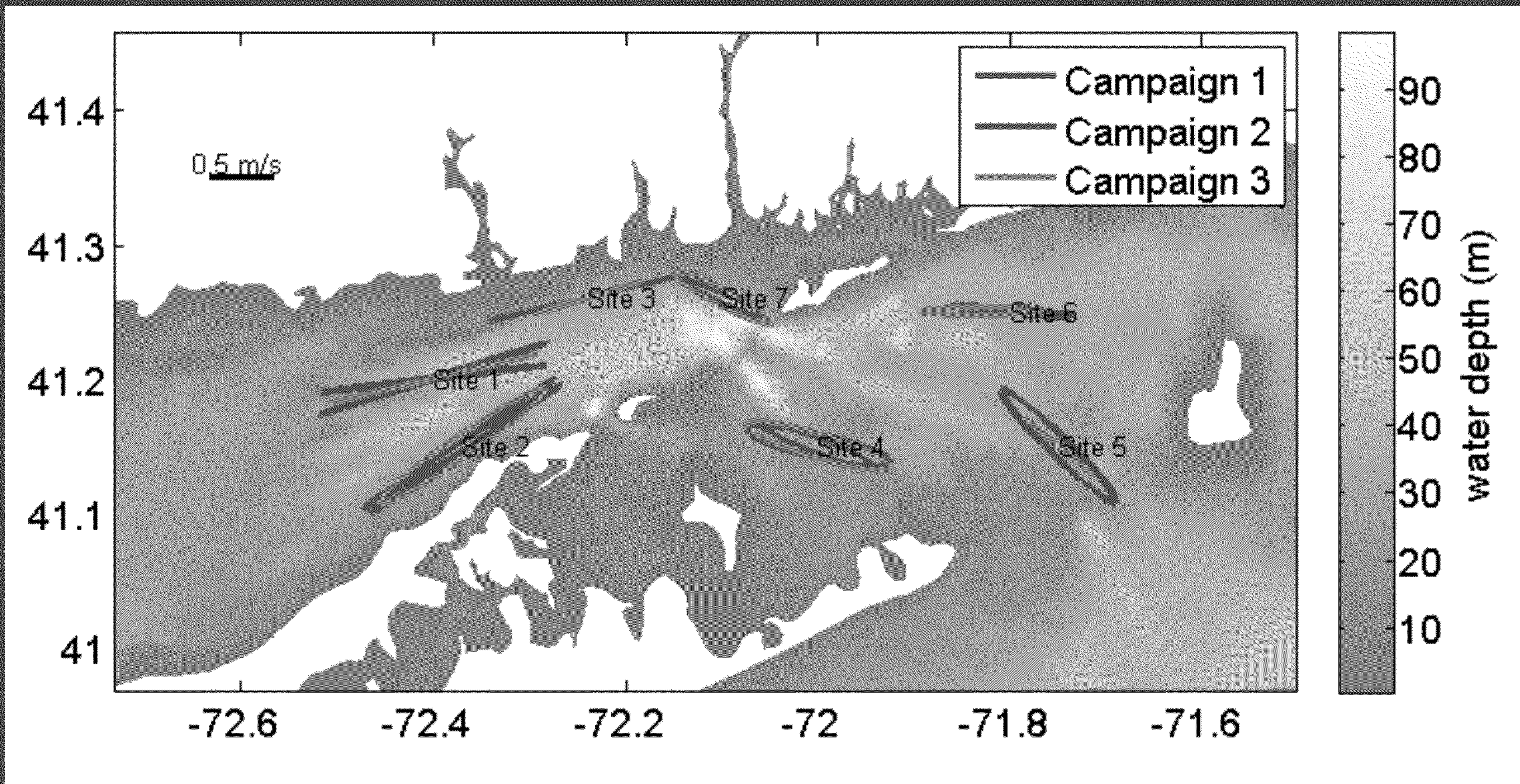
Nortek ADCP means at ~0.6m from seafloor



Mean velocity vectors at each moored station from the Nortek ADCP near the seafloor. The velocity scale is shown on graphic.

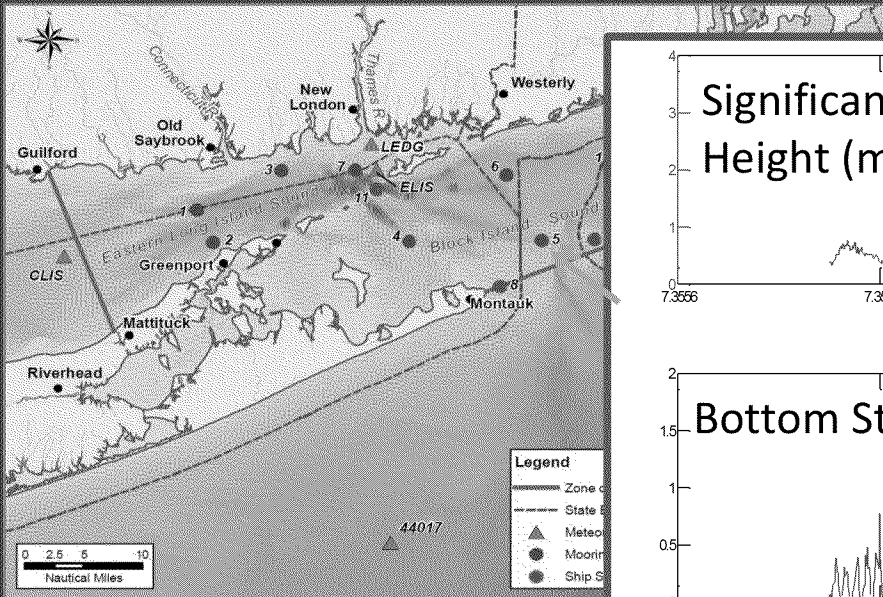
Tidal Current (M2) Amplitudes

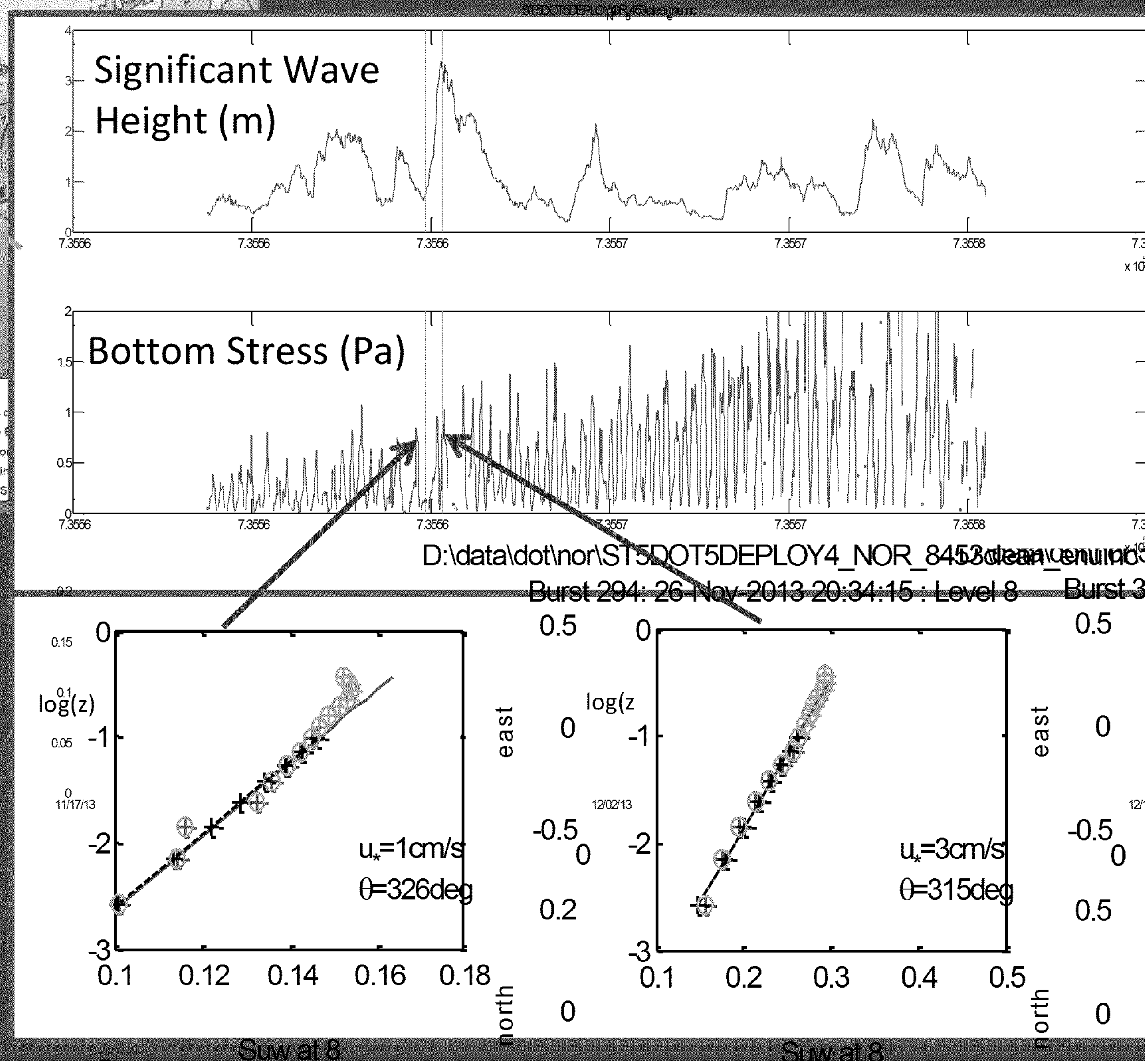
M2 Tidal Constituents



M2 ellipses for depth-average velocities from RDI ADCP measurements from the three campaigns (colors) and for FVCOM model (black) at all seven DOT stations. The grey shading represents mean water depth.

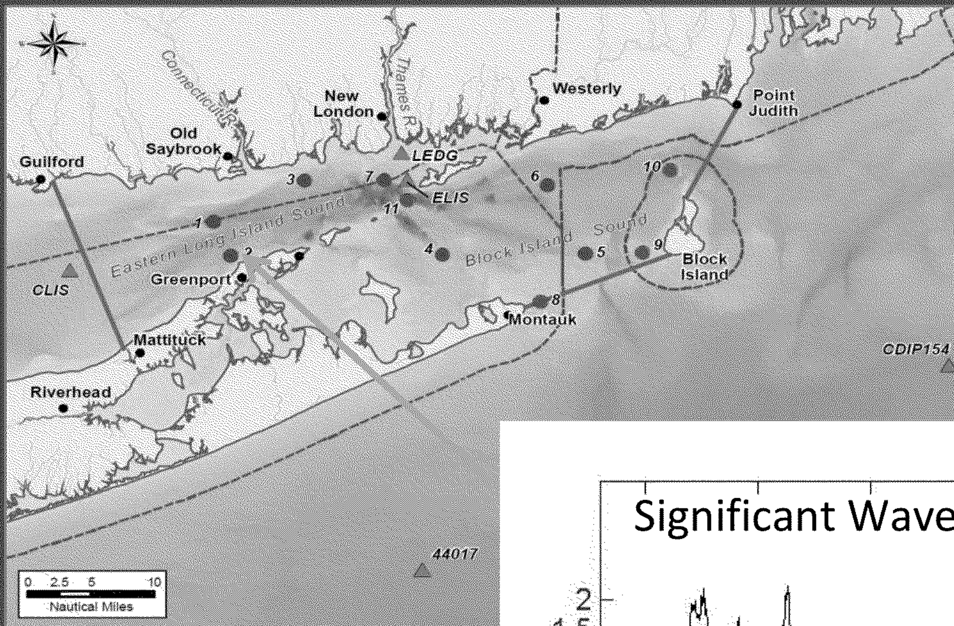
Wave and Stress Measurements

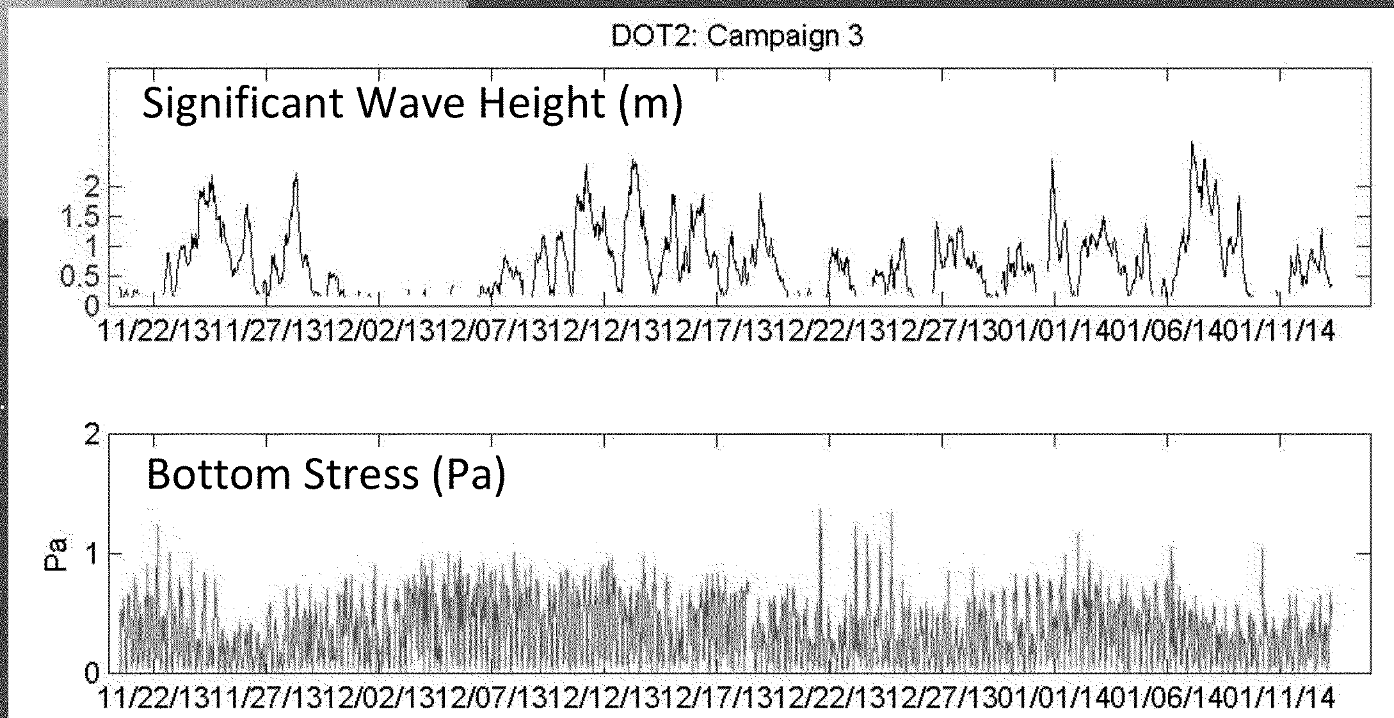




The variation of u(z) with log(z) for ensembles 297 and 317

Wave and Stress Measurements

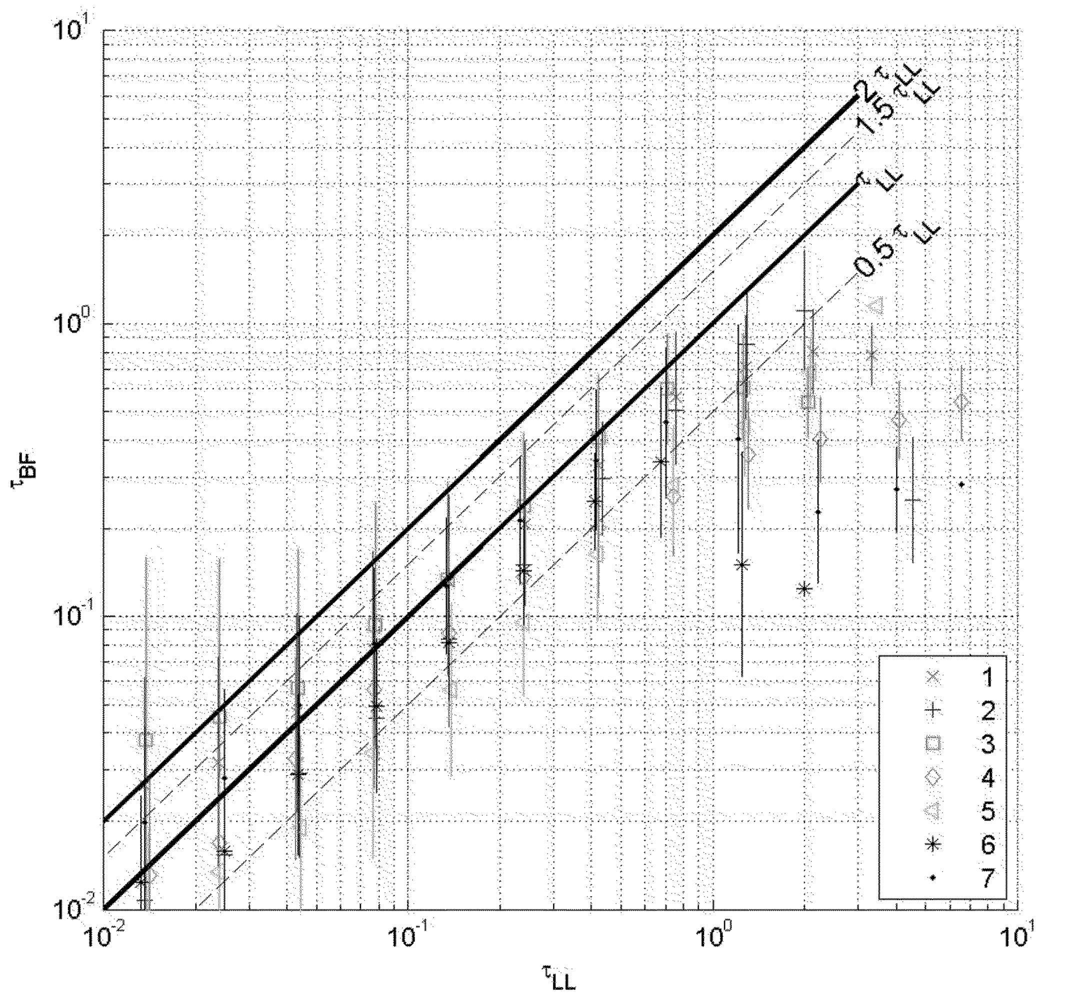




Characteristics at Station DOT2 during Campaign 3:
Top: Significant wave height (in m).
Bottom Stress.

Bottom Stress Drag Coefficient Evaluation

Measurements using the Log Law method (LL) support the use of Bulk Formula (BF) with C_d =0.0025.



Summary of stress magnitude measurements using the log law and the bulk formula with C_d=0.0025. To suppress the noise inherent in turbulent quantities, measurements were bin-averaged. The key shows the stations numbers.

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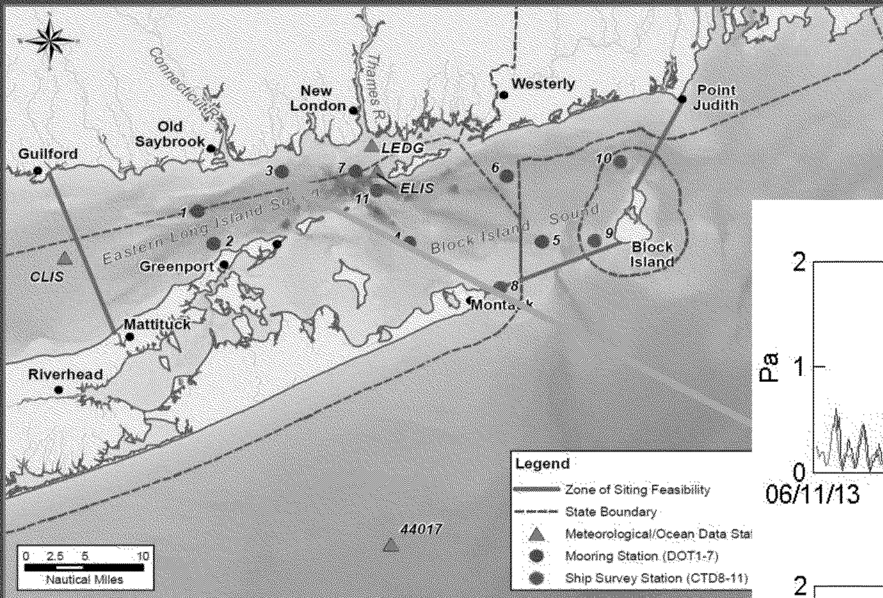
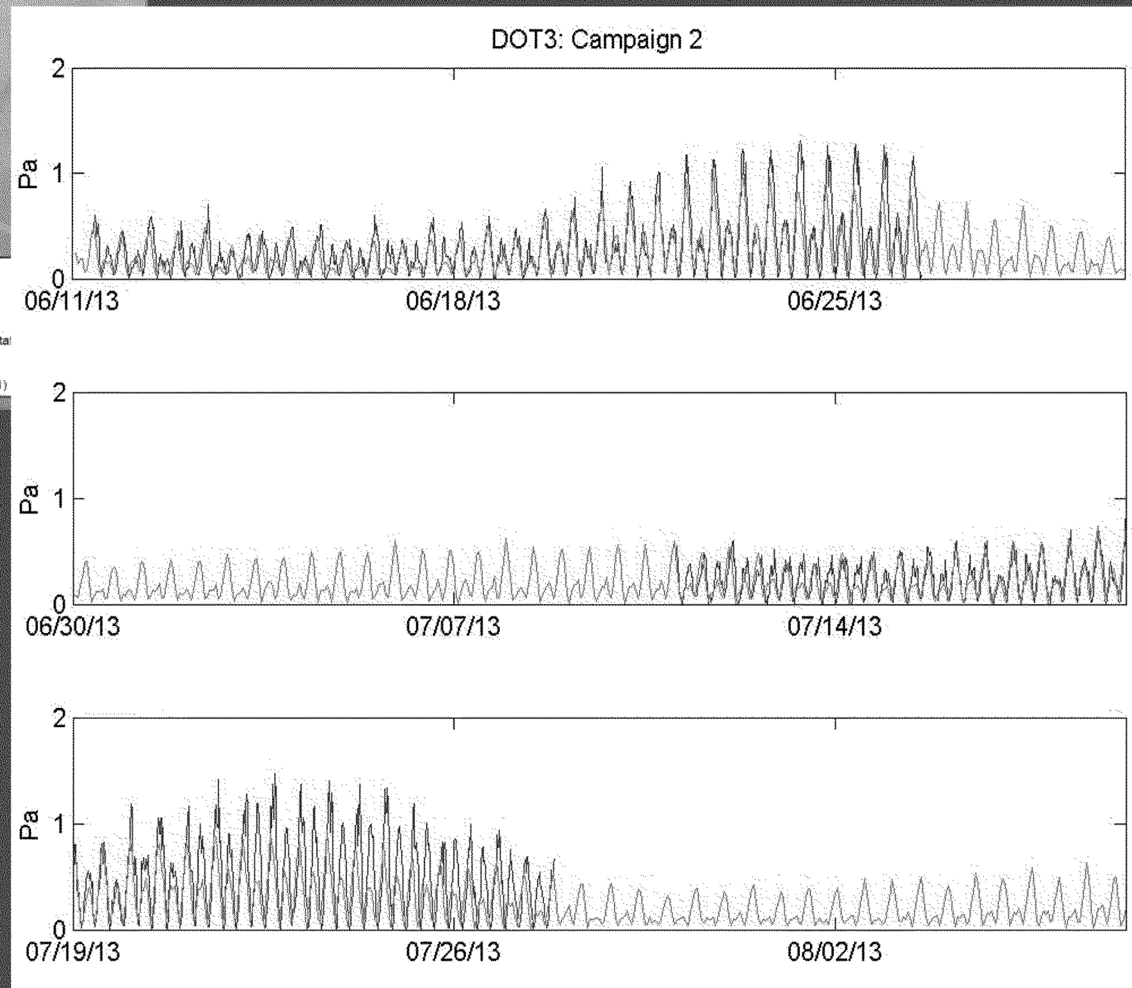
3. Evaluation of Bottom Stress in Model



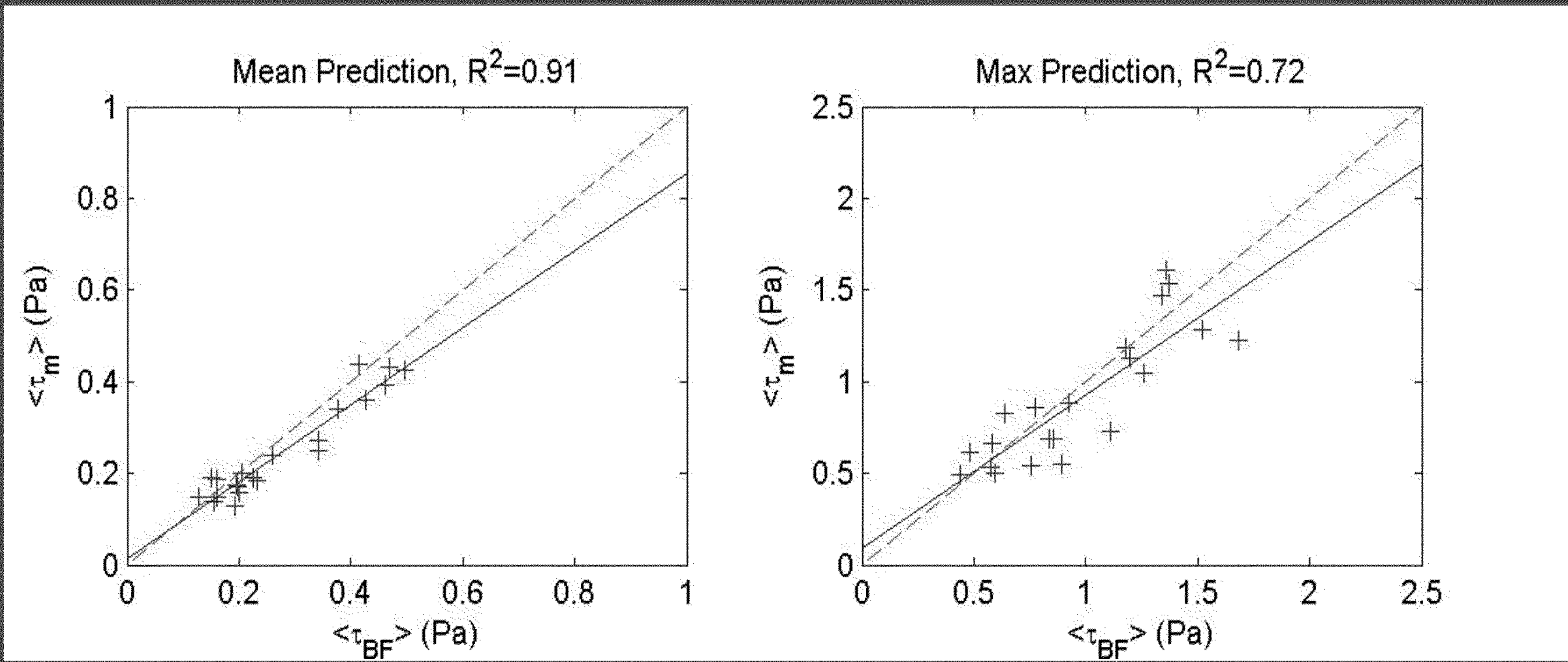
Model simulations reproduce tidal and the spring-neap variations on observed stress



Model-predicted bottom stress at Station DOT3 during Campaign 2 in the summer of 2013 (magenta line). The blue line shows the measured stress using the bulk formula.

3. Evaluation

- Model and observations agree on the campaign mean and maximum stress magnitudes.
- Model can effectively discriminate between places where the maximum measured stresses are large (>1 Pa) and those where they are smaller (<1Pa).



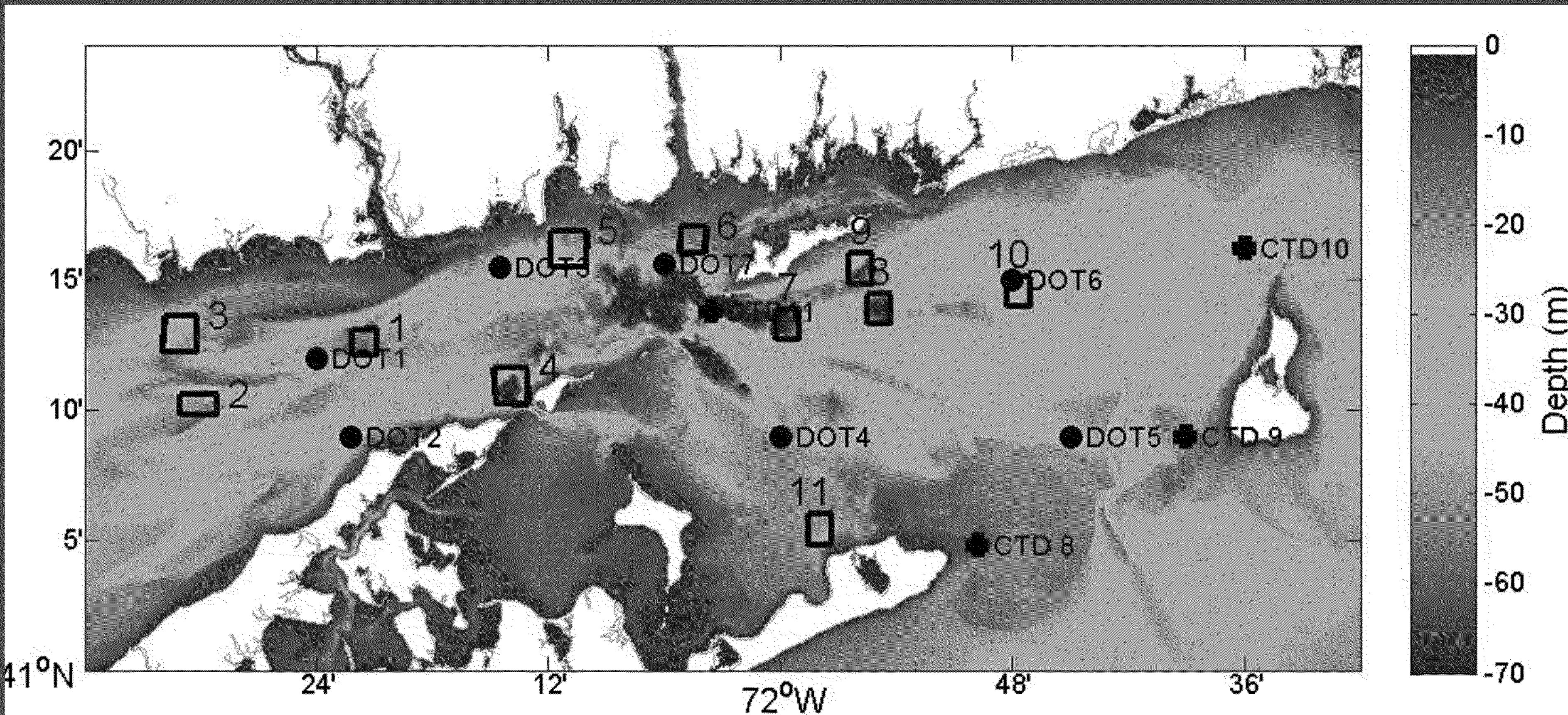
Left: Comparison of model predicted bottom stress magnitudes and mean bottom stress observed during the three campaigns. Points would all lie on the red dashed line if the model and data were in perfect agreement. The blue solid line shows the ordinary least-squares regression line which has a correlation coefficient of 0.91.
Right: Comparison of the predicted and observed maximum stress magnitudes. The correlation coefficient was 0.72.

4. Analysis

- Find maximum bottom stress magnitude at each point in the ZSF in the three Campaigns
- Compare values at sites identified in the screening process
- Simulate period of a severe storm (Superstorm Sandy) and compare maximum stress magnitudes

4. Analysis *(cont.)*

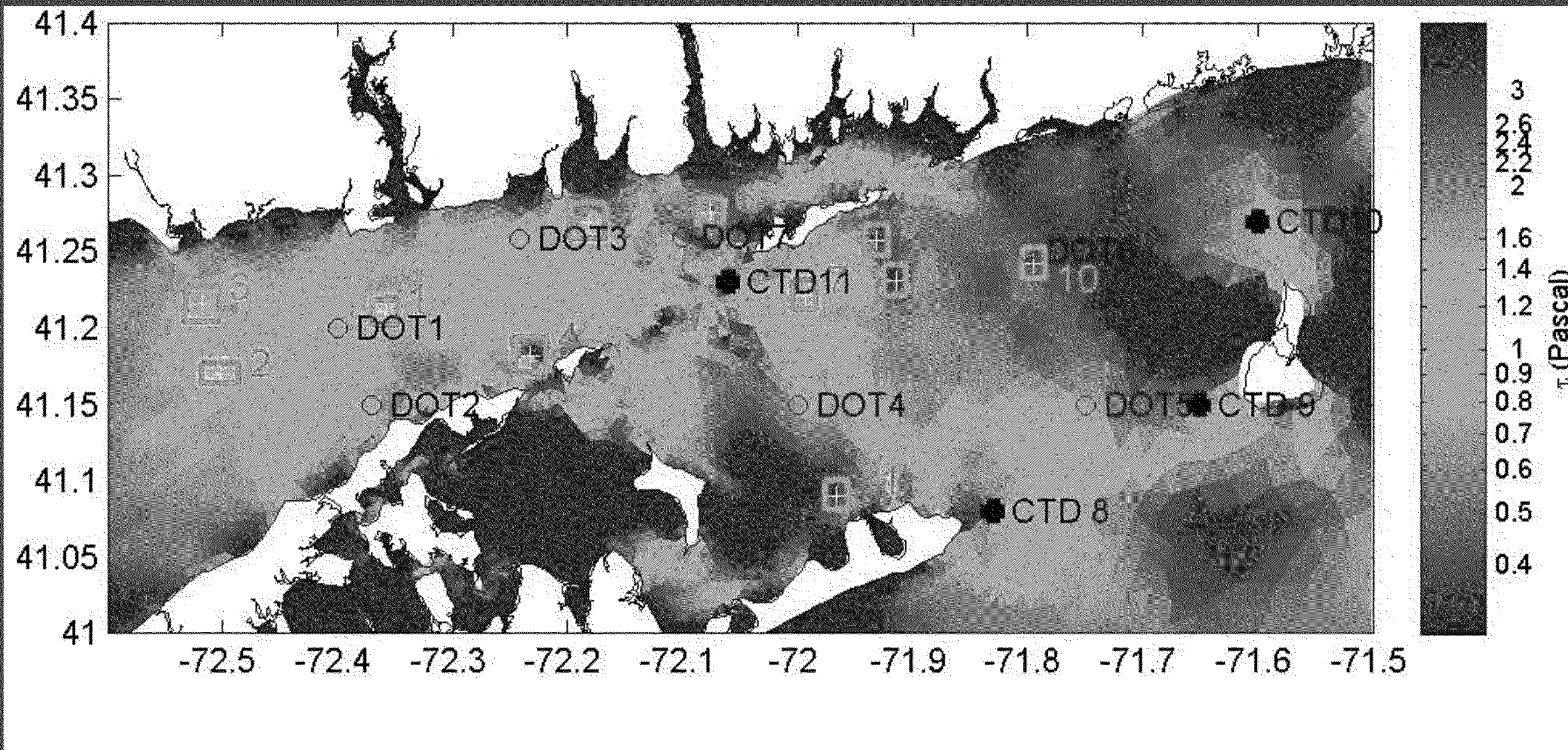
Bathymetry and locations of potential sites



Water depth and 11 potential dredged material disposal sites (open boxes) as identified during the initial screeningprocess. Sites 1 and 6 are the active disposal sites (CSDS and NLDS, respectively). The seven mooring stations ('DOT') are identified by full circles; the four additional ship survey stations ('CTD') are identified by crosses.

4. Analysis *(cont.)*

- Spatial differences are much larger than seasonal variations
- Stress is high in much of ZSF



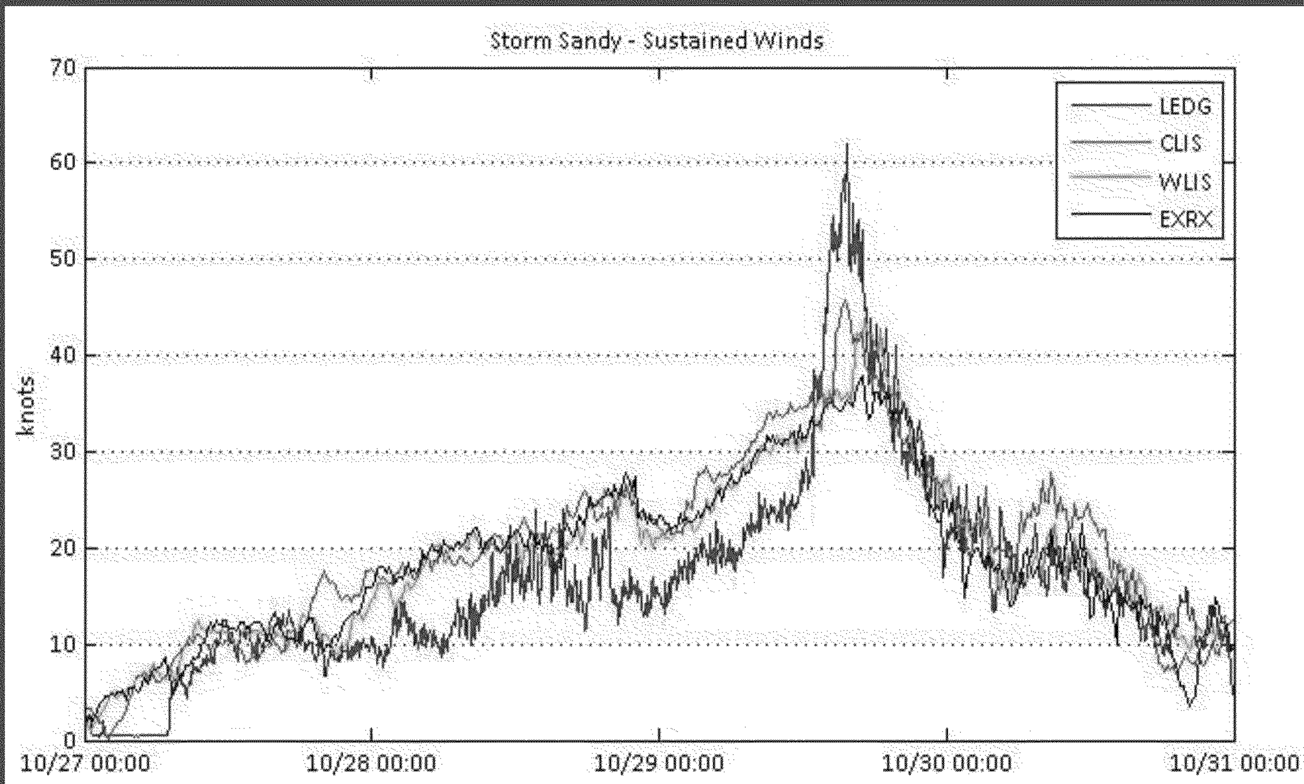
Maximum bottom stress during Campaign 3 (November 20, 2013, to January 16, 2014) for storm conditions (i.e., due to the prinapal tidal current constituents and the seasonal mean flow, as well as wind).

4. Analysis *(cont.)*

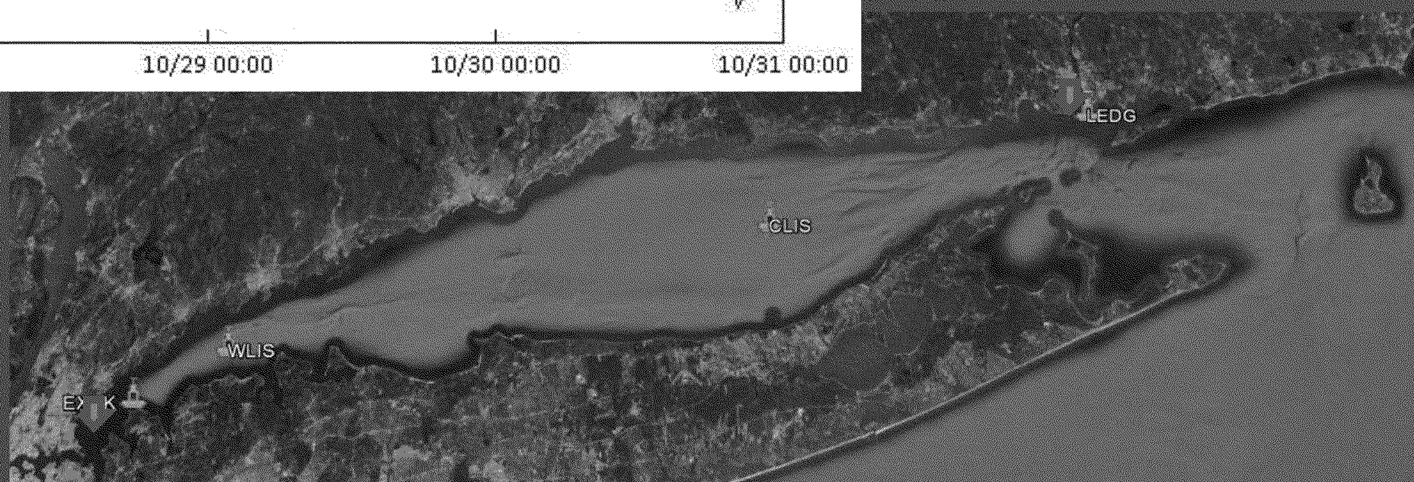
Maximum Bottom Stress (Pa) during Storm Conditions at Potential Dredged Material Disposal Sites

Potential Disposal Site			**Maximum Bottom Stress** (Pa)		
			1. (spring)	**2. (summer)**	**3. (winter)**
ELIS	1	Cornfield Shoals Disposal Site	1.17	1.31	1.24
	2	Six Mile Reef Disposal Site	0.92	1.09	1.00
	3	Clinton Harbor Disposal Site	0.72	0.71	0.81
	4	Orient Point Disposal Site	0.52	0.61	0.48
	5	Niantic Bay Disposal Site	0.73	0.97	0.84
	6	New London Disposal Site	0.60	0.70	0.69
BIS	7	Fishers Island-west	0.79	0.91	0.86
	8	Fishers Island-east	0.49	0.51	0.39
	9	Fishers Island-center	0.39	0.50	0.38
	10	Block Island Sound Disposal Site	0.49	0.63	0.44
	11	North of Montauk	0.31	0.31	0.34

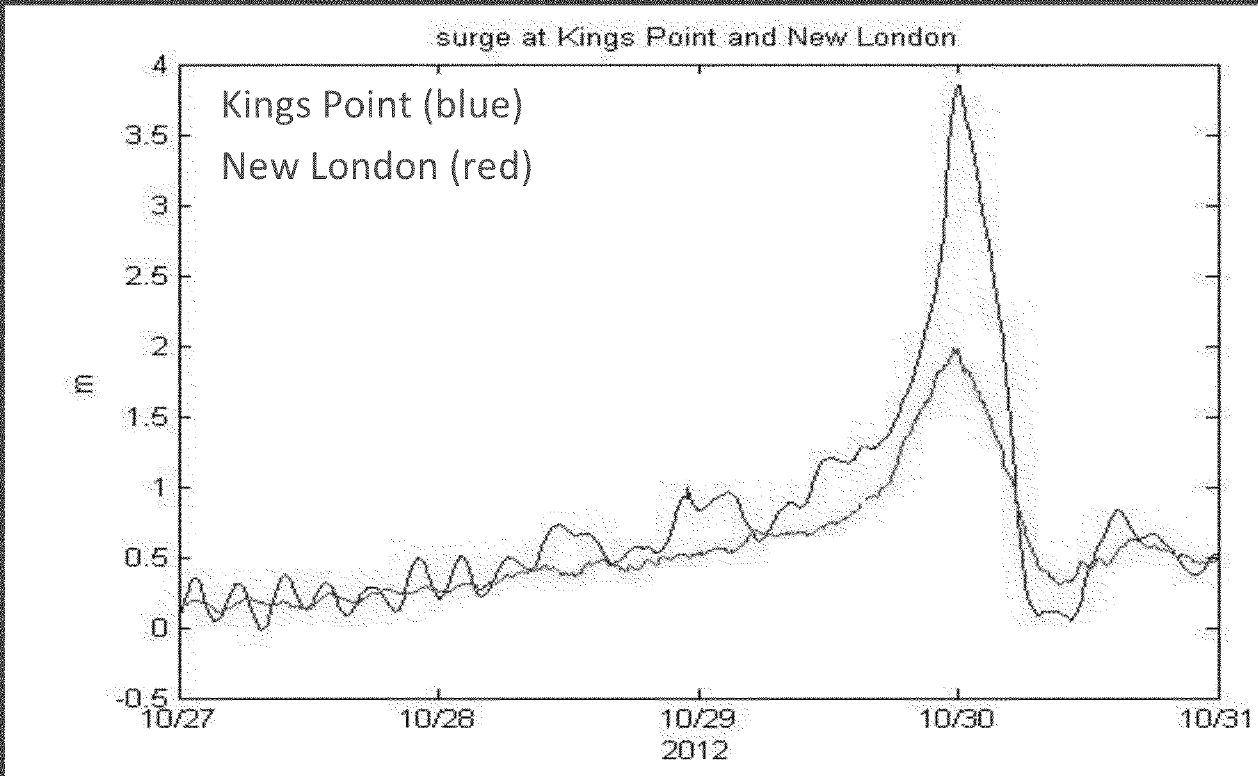
4. Analysis *(cont.)*



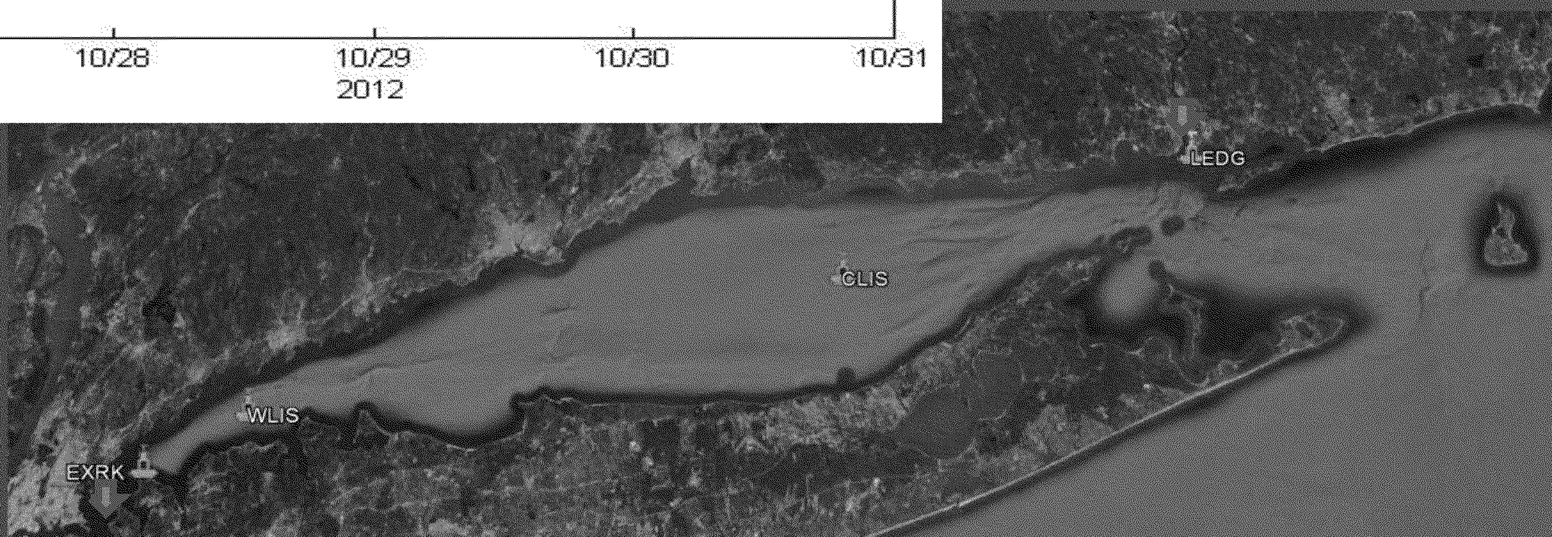
Superstorm Sandy: Sustained Winds



4. Analysis *(cont.)*

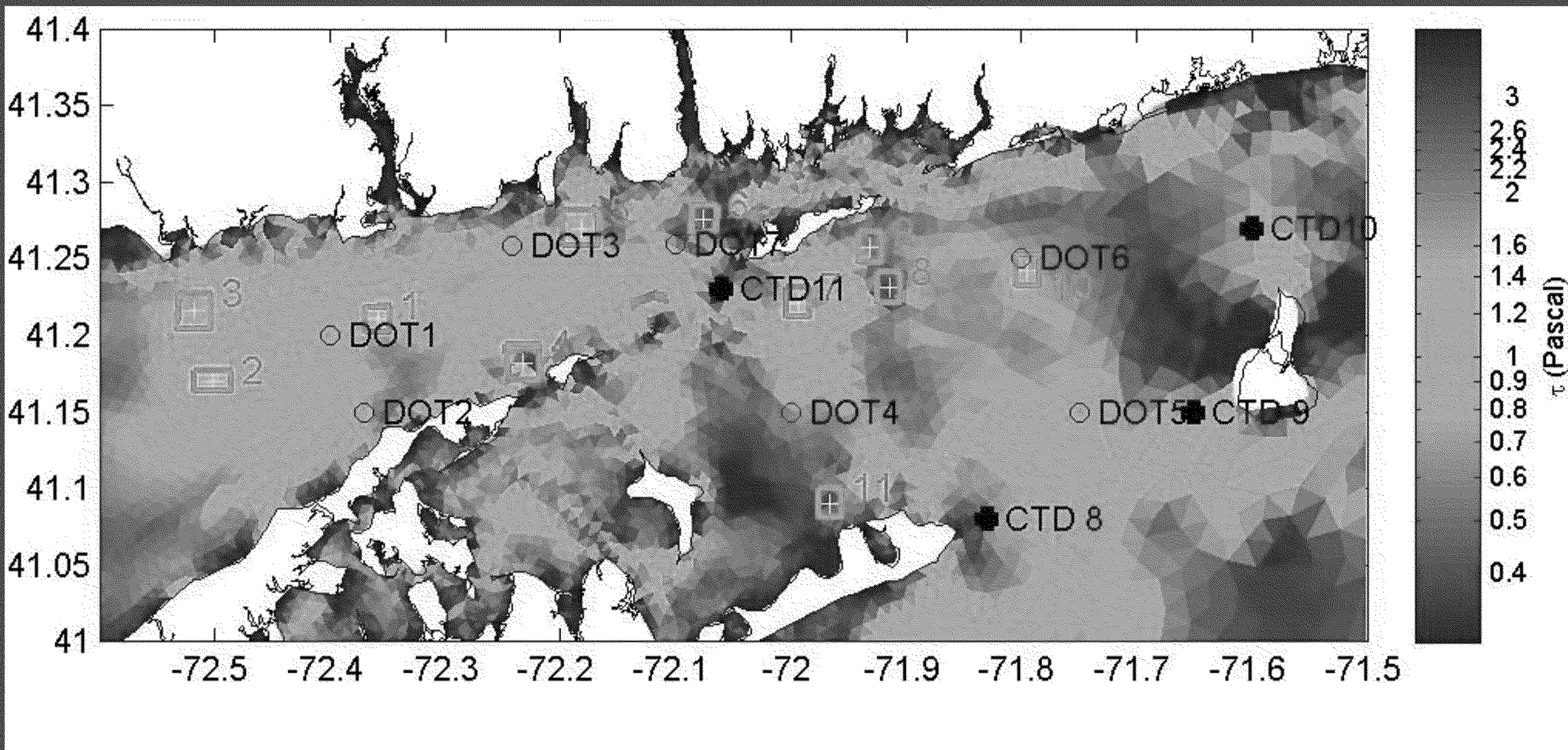


Superstorm Sandy: Storm Surge



4. Analysis *(cont.)*

Superstorm Sandy created higher maximum bottom stresses in some areas



Maximum bottom stress simulated for the period October 28 to 31, 2012 when Superstorm Sandy passed over New England.

4. Analysis *(cont.)*

Potential Disposal Site			Superstorm Sandy Conditions: Bottom Stress (Pa)
ELIS	1	Cornfield Shoals Disposal Site	1.16
	2	Six Mile Reef Disposal Site	1.26
	3	Clinton Harbor Disposal Site	0.87
	4	Orient Point Disposal Site	0.53
	5	Niantic Bay Disposal Site	0.99
	6	New London Disposal Site	0.48
BIS	7	Fishers Island-west	1.17
	8	Fishers Island-east	0.46
	9	Fishers Island-center	0.55
	10	Block Island Sound Disposal Site	0.73
	11	North of Montauk	0.39

4. Analysis *(cont.)*

Stress Threshold for Erosion on Seafloor:

- Defined as the level of stress at which dredged material in a disposal area will be mobilized
- Depends upon sediment grain size, fraction of clay, volume fraction, level cohesiveness
- Based on a review of the literature, we choose 0.75 Pa as the design threshold

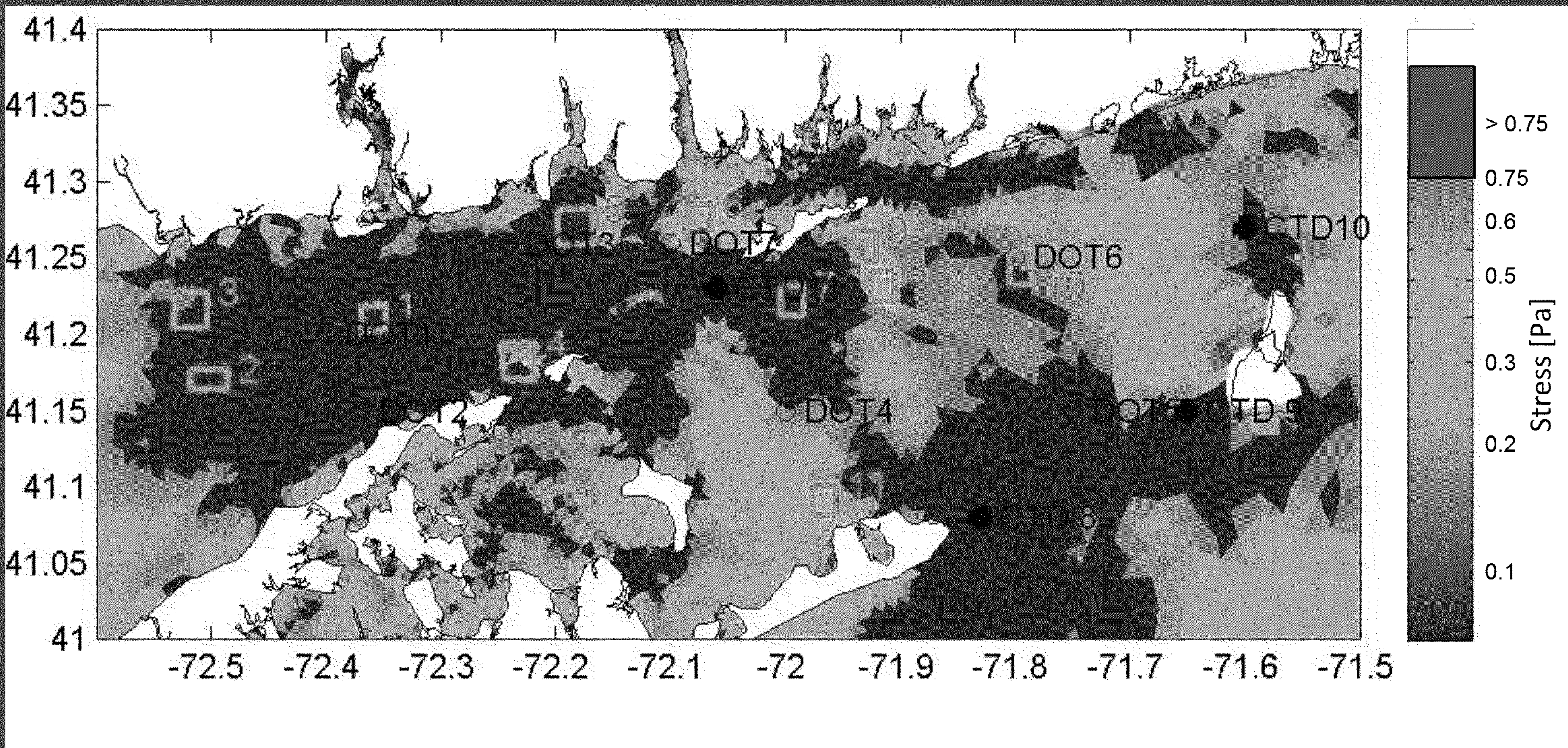
4. Analysis *(cont.)*

Comparison of Maximum Bottom Stress (Pa) for Potential Dredged Material Disposal Sites in the simulations of the three Observation Campaigns and Superstorm Sandy.

Potential Disposal Site				Maximum Stress in Simulations (Pa)	
ELIS	**BIS**	**No.**	**Site Name**	**Group**	**Highest Value**
●		1	Cornfield Shoals Disposal Site	>1	1.31
●		2	Six Mile Reef Disposal Site		1.26
	●	7	Fishers Island-west Disposal Site		1.17
●		5	Niantic Bay Disposal Site	0.75-1.0	0.99
●		3	Clinton Harbor Disposal Site		0.87
	●	10	Block Island Sound Disposal Site	<0.75	0.73
●		6	New London Disposal Site		0.69
	●	9	Fishers Island-center		0.55
●		4	Orient Point Disposal Site		0.53
	●	8	Fishers Island-east		0.46
	●	11	North of Montauk		0.39

5. Summary

Areas with maximum bottom stress exceeding the 0.75 Pa threshold during the simulation of Superstorm Sandy (screened as a uniform brown layer). Areas with bottom stress below 0.75 Pa are scaled (see color key on the right).



5. Summary (cont)

Sites 1, 2, and 7
(Cornfield Shoals, Six Mile Reef, and Fishers Island - west) have high maximum stresses.

Sites 4 and 10
(Orient Point DS and Block Island Sound DS) show maximum stress below the 0.75 Pa threshold at the center of the site, but have values in excess of 0.75 Pa within the boundary.

Sites 5 and 3
(Niantic Bay and Clinton Harbor) show maximum stresses exceeding 0.75 Pa but less than 1 Pa.

Site 6
(New London DS) is the only site in Eastern Long Island Sound with maximum bottom stress below the 0.75 Pa threshold.